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PUBLICATIONS OF THE
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No. 1

A PLAN FOR THE BIOLOGICAL INVESTIGATION OF THE WATER AREAS OF ONTARIO

BY

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UNIVERSITY OF TORONTO

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A PLAN FOR THE BIOLOGICAL INVESTIGATION OF THE WATER AREAS OF ONTARIO

During the past two years a considerable amount of attention has been given to the organization within the Department of Biology of the University of Toronto of a research branch to be devoted to the investigation of the water areas of Ontario with reference to existing biological conditions and economic problems. It has been proposed to carry on the work of this branch under the title "Ontario Fisheries Research Laboratory", some distinction being necessary to indicate its scope and outlook, as also to draw a line of demarcation between this and other interests of the Department, and being especially advisable in view of the work now conducted in marine biology. Moreover a special name is advisable in order to establish a basis for the better classification of publications which in this instance may be expected to appeal for the most part to those interested in general limnology or in conservation and fishery problems. Apart from the provision of apparatus and equipment the initial step in the formation of the new organization was the appointment of Professor W. A. Clemens as Limnobiologist, an arrangement which renders possible full time service and supervision of field operations at any part of the year, and also provides for continuous investigation of the collected material and data. The first reports of a technical nature are now in course of publication. They refer principally to some special fisheries work on Lake Erie, but will be followed by a series of papers dealing with Lake Nipigon. The latter will be in a sense the products of the first field party, consisting of Professor Clemens and other members of the university and museum staffs who spent the greater part of the summer of 1921 in practical operations on the lake.

The study of the scientific aspects of fishery questions is one for which the University Biological Laboratory is

especially fitted. Its position as part of the provincial educational system identifies its interest in matters touching the natural resources with that of the province at large. Nearly thirty years ago the desirability of a systematic biological survey of the provincial waters was urged by Professor Ramsay Wright ('92), and in the interval the need of a thorough investigation of the factors underlying the distribution of aquatic organisms has become increasingly evident. Neither individual efforts nor the collective participation of members of the university staff in the work of the Georgian Bay Biological Station, which was maintained for some years in that region, led to the consideration of any measures upon which the hope of a continuous if not permanent organization for the biological investigation of provincial waters could be based. That the latter now appears within the range of possibility is therefore a matter of some satisfaction.

The following pages are devoted to a general discussion of the proposed line of investigation. This is mainly a matter of the relation of limnology at large to local conditions as represented by the waters of the Province of Ontario, with particular reference to general and economic problems. The principal topics considered are (a) the relation of the proposed investigation to the practical and administrative aspects of conservation, (b) the foundations of limnology, (c) the extent of the local fish fauna, and (d) the chief physical features of the provincial water areas, including, first, the provincial portions of the Great Lakes and, second, the land-enclosed areas, from the point of view of their limnological study and the nature of economic questions. Except in the case of the fishes, which occupy a central position in respect of the economic outlook, no reference will be made to particular groups of organisms.

The distinction often made between theoretical and applied or economic considerations is generally recognized as purely a matter of convenience in description. Its value, if any, consists in denoting the purpose or outlook implied. There is, however, a relation between investigation of an

economic kind or purpose and practical or administrative measures. In Canada, as elsewhere, various questions, partly of revenue, partly of control of exploitation of natural resources, wastefulness and many other matters having to do with natural wealth, gave rise long ago to regulative measures, and more recently to a public movement in the direction of conservation. More intricate perhaps than in other fields, because of the elusiveness of wild life and the obscure factors upon which its success depends, the problems of conservation as applied to living organisms were early recognized as involving scientific knowledge of an exact kind. On the other hand, the desire to arrive at what would usually be considered expert information has, in a great many instances, painfully evident in the literature of conservation, given rise to confusion as to the extent and method of its application, resulting in the concealment of many sound practical ideas in a mass of information relating to general natural history. Measures of conservation as applied to the fisheries, including under the term also regulatory legislation, which has or ought to have a similar effect, consist broadly in striking a reasonable balance between forces of utilization and those of natural and artificial replacement. In this process the administrative function is the first necessity; technical practice, as, for example, fish breeding and economic industrial processes, is next in order of urgency, while scientific investigation is accessory or contributory. Its value consists in the analysis of all factors physical, chemical and biological, and in drawing attention to particular factors the neglect of which may result in ineffective practice or futile legislation.

The early development of fresh water biology in Europe, in many respects the foundation of similar work in America, established first of all the identity and distribution of the various species of aquatic organisms, and, second, the association of these organisms with environmental conditions; to a certain extent also it carried out the classification of these conditions on the basis of their mutual associations. After nearly one hundred years of individual, and for the

most part isolated, effort on the part of early biologists, among whom will be found some whose names are foremost in the records of biological science, it gave rise, mainly through the efforts of Forel, Apstein, Zacharias, Zschokke and others, to an attempt at correlation of limnological results, best expressed by Zacharias ('91) and his co-workers in their compilation dealing with the fauna and flora of fresh water. The extensions of this earlier work not only resulted in a more thorough enumeration of species in local European areas, but also gave rise to the study of physical and chemical factors, environmental communities, plankton determination, and the formal and institutional recognition of limnology, as best exemplified by the complete limnological study of Lake Geneva by Forel ('92) and the establishment through Zacharias ('93) of the Biological Station of Plön after the pattern of the marine institution at Naples.

American limnology, which naturally had a later origin, has the same foundation and in some respects a similar development. That it may be said to have only recently arrived at the stage of collective recognition is due to a variety of circumstances, including no doubt the great area to be covered in the classificatory study of the various groups, and the fact that the accumulation of information bearing in one way or another upon general limnology, as, for example, in the fisheries, natural resources in general, conservation and the like, has been almost from the beginning the particular interest of government bureaus, and of surveys and commissions under state or national auspices. Though the study of the water areas as entities, or complete physical-biological complexes, has not yet arrived at a stage of development commensurate with its great importance, its recognition is at least assured. As long ago as 1887 the principle was advocated by Professor Forbes ('87) and its application is observable in his later work ('08) in association with Richardson, Kofoid ('03) and others on the Illinois river system. The same principle is exemplified in the work of others, some of whom owe their inspiration to the example of Professor Forbes, including that of Reighard ('94) on

Lake St. Clair, Ward ('96, also '18) on Lake Michigan, Birge and Juday ('11) on the inland lakes of Wisconsin, the study of physical factors and their association by Needham and Lloyd ('16), Shelford ('13) and Adams ('13), and finally the recent work of Evermann and Clark ('20) on Lake Maxinkuckee, Indiana, in some respects the most complete study of an individual lake yet available in America. Not a small part in the collection of data bearing upon limnology has been taken by state organizations, by the establishment of temporary or permanent biological field stations (Ward '98, Needham and Lloyd '16) and the recognition of the state university as the natural centre of such investigation. On the other hand, while the results of investigation wherever conducted have at least some measure of general applicability, it is unfortunate that the study of limnology has not proceeded along more uniform and better organized lines. The paucity of information concerning the water conditions of all the Canadian Provinces and certain of the States is in marked contrast to the extensive information available in respect of certain States, notably Illinois and Wisconsin. What is chiefly significant, however, is the contrast between European and American efforts in general in view of the opportunities offered. If there is any one single outstanding fact concerning the importance of American water areas, it is the fact of the existence of a mid-continental area of some 80,000 square miles represented by the Great Lakes of the St. Lawrence basin. Parts of a great international waterway, locally shared by one Canadian province, and eight states of the Union, the centre of an old established fishery, the Great Lakes constitute in all respects the outstanding fresh water area of the world. Had the example of Forel and of Zacharias been followed we should have had available on the Great Lakes either an extensively equipped limnological institution or at least some specific organization devoted to the study of the area in all its aspects. The question is not one of simply local concern, though it is evident from geographical considerations

that it is one in which the Province of Ontario is vitally interested.

While various groups of aquatic organisms are directly or indirectly involved in questions of an economic kind, it is obvious that the fishes are the ones chiefly concerned. To what extent are they represented in Ontario? The commercially recognized fishes, including the more desirable species, lake trout, whitefish, ciscoes, tullibee, doré and sturgeon, as well as the coarser species, pike, carp, mullets and catfish, and the game fishes, principally speckled trout, small and large mouthed bass and maskinonge, are collectively a small, though very important part of the local fauna. The number of fish species, fresh water and marine, occurring in Canadian and Newfoundland waters, is stated by Halkett ('13) to be 569. Evermann and Goldsborough ('07) place the number of fresh water species occurring in Canada as a whole at 145, representing 67 genera and 25 families. In the first computation of the number occurring in Ontario (Wright '92) reference is made to forty or fifty species, but the local records were at that time very incomplete, and the computation was doubtless based to some extent on the earlier reference compilation of Jordan and Gilbert ('83) later greatly extended and revised by Jordan and Evermann ('96). The most complete index of Ontario fishes is that of Nash ('08), based partly on the foregoing compilation checked against collections from various points in the province. The total number is placed at 112, representing 69 genera and 26 families. Though this computation precedes some other taxonomic work, notably that of Jordan and Evermann ('11), and though much is yet to be done in the matter of critical diagnosis of species from individual areas, it is probable that the number of species occurring in Ontario is in the neighbourhood of 125. While this representation is fairly large as to species and apparently very inclusive as to families and genera as compared with Canada as a whole, it is probable that the number of species occurring at any one point is less than half the total. The number reported by Nash ('13) for the Toronto region is 49 and

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75
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HUDSON BAY
MANITOBA
Severn River
Winisk River
Ekwan River
Attawapiskat River
JAMES BAY
Kapiskau River
Albany River
Albany River
L. St. Joseph
QUEBEC
Moose River
L. Seul
Lake Nipigon
Lake of the Woods
Rainy Lake
Abitibi Lake
MINNESOTA
LAKE SUPERIOR
Timagami Lake
L. Nipissing
Ottawa River
North Channel
GEORGIAN BAY
WISCONSIN
Green Bay
LAKE MICHIGAN
LAKE HURON
Muskoka Lakes
Rideau L.
St. Lawrence River
L. Simcoe
Scugog L.
Rice L.
LAKE ONTARIO
MICHIGAN
NEW YORK
St. Clair Lake
LAKE ERIE
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
PROVINCE OF ONTARIO
SCALE, 140 MILES TO 1 INCH

MAP I.

HUDSON BAY
MANITOBA
O
S
JAMES BAY
P
D
QUEBEC
Albany River
Lake Nipigon
Abitibi Lake
P
MINNESOTA
LAKE SUPERIOR
Timagami Lake
L. Nipissing
Ottawa River
North Channel
GEORGIAN BAY
WISCONSIN
Green Bay
LAKE MICHIGAN
LAKE HURON
O
LAKE ONTARIO
S
MICHIGAN
D
NEW YORK
St. Clair Lake
LAKE ERIE
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
PROVINCE OF ONTARIO
SCALE. 140 MILES TO 1 INCH
GEOLOGICAL FORMATIONS
P = Pre-Cambrian
O = Ordovician
S = Silurian
D = Devonian
95
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Map II.

by the writer ('15) for Georgian Bay 48. These figures correspond fairly well to those given by Evermann and Clark ('20) for Lake Maxinkuckee (64) and other single areas (vol. I, p. 262).

The total extent of water area in Ontario as estimated is in the neighbourhood of 80,000 square miles,[1] probably a very conservative estimate when it is realized that a large part of the province is as yet only superficially surveyed. As compared with the total area of the province itself, 407,262 square miles, the submerged portion constitutes about one fifth. This relatively large extent of water area is accounted for in part by the provincial portion of the Great Lakes and by the occurrence within the province of the great Precambrian region, the rock depressions of which, left by the glacial period, now lodge an almost continuously connected series of overflow basins, ranging in size from the smallest ponds and muskegs to lakes of considerable or even of large size. Both geographically and from the point of view of their different economic associations, the Great Lakes and land-enclosed areas may best be considered separately. The former include as provincial waters the Canadian portions of Lakes Superior, Huron, together with Georgian Bay and the North Channel, St. Clair, Erie and Ontario, a total provincial area of some 38,000 square miles in extent, with some 1,500 or 2,000 miles of shore line forming the land boundary of the province on its south and west sides. The land-enclosed area, estimated at 41,385 square

[1]The figures reported are taken for the most part from the Atlas of Canada; published by the Department of the Interior, Ottawa, 1906. Those contained in the following table are from White ('05). Cf. also Map I.

Physical Data, Great Lakes

Lake	*Area*	*Length*	*Width*	*Ontario Drainage*	*Maximum Depth*	*Maximum Height*
	sq. mi.	*mi.*	*mi.*	*sq. mi.*	*feet*	*feet*
Ontario	7053	193	53	11,342	738	246
Erie	9968	241	57	5,480	210	572
St. Clair	503	26	24	41,160	180	575
Huron	22978	206	101	35,400	750	581
Superior	32060	350	160	30,780	1012	602

miles, includes lakes and rivers distributed unequally over a land area which for convenience may be divided into five portions, each having a more or less definite facies, depending originally no doubt upon the geological foundation and the final effects of glacial action. These portions are:—

(*a*) The south western peninsula, or that portion lying to the west of a line connecting the south end of Georgian Bay with the north shore of Lake Ontario to the west of Toronto. This portion comprises the older agricultural part of the province, is noteworthy for the paucity of water areas, and is underlain by strata of Silurian and Devonian age (cf. Map II)* covered by glacial soil deposits of considerable thickness. It is also that portion of the province having the principal frontage on the Great Lakes.

(*b*) A portion lying to the south of a line connecting the southern end of Georgian Bay with Lake Ontario in the region of Kingston. It forms the north shore of the larger part of Lake Ontario, contains some characteristic lakes, including Simcoe (300 square miles), Rice (27 square miles) and Scugog (39 square miles), is underlain by Cambrian and Ordovician strata, and is transitional in many ways between the portion already described and the Precambrian area to the north.

(*c*) The northern Precambrian area of relatively great extent, including the Laurentian Highlands, and characterized by its exposed igneous and metamorphic rocks with innumerable lakes distributed over its surface. The larger lakes include Nipissing (330 square miles) and Nipigon (1,730 square miles).

(*d*) A north west portion containing the Lake of the Woods (1,851 square miles) and similar water areas lying beyond the height of land, and related both in aspect and origin (Lake Agassiz) to Lake Winnipeg and other lakes with the drainage system of which they are connected, though underlain by rock formations similar to the foregoing.

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*Prepared under the supervision of Professor W. A. Parks, University of Toronto.

(*e*) The Hudson Bay drainage area, a region characterized by the broad coastal plain, and on the whole moderately inclined river basins of the Severn, Moose and Albany Rivers, and underlain in part with strata of Devonian age, an area hitherto, on account of its inaccessibility, only superficially considered in its relations to the province, but presenting as a matter of fact some 600 miles of provincial marine coast line.

From the point of view of limnological investigation the Great Lakes offer almost unlimited opportunity. Except for the identification of aquatic organisms and, at least to some extent, their distribution, the most detailed information concerning the lake area refers to soundings and levels,[1] of importance in navigation, water supply and sewage disposal, of interest to municipalities, and practical matters relating to the fisheries.[2] Information is desirable concerning a great variety of physical factors, depth and seasonal variation of water temperatures, suspended materials, dissolved substances and absorbed gases, light penetration, substratum, as well as dynamic forces concerned in transportation of materials, water currents and circulation. Of especial importance are also environmental or ecological associations, in respect of which there are not only great local variations entering into the life cycle of organisms, but also marked general contrasts between individual lakes as complete environmental entities on a large scale. Thus even a superficial comparison of Lake Superior with Lake Erie in respect of their geographical position and physical characteristics reveals contrasts of geological formation, depth, transparency and temperature, the last-named

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[1]Admiralty, Dominion and United States Charts, listed Department of Naval Service, Catalogue of Official Canadian Government Publications of Use to Mariners, Ottawa, 1920. Cf. Report of the International Waterways Commission, same reference; also Russell ('95), White ('15).

[2]Reports of Dominion Department of Marine and Fisheries, Department of Naval Service, Commission of Conservation, United States Bureau of Fisheries; Ontario Department of Game and Fisheries, Geological, Natural History and Fish Commission publications of individual States.

difference doubtless involving several factors in addition to the more obvious ones of depth and maximum latitude difference amounting to some eight degrees. Furthermore the development of the Great Lakes is one of the most interesting chapters of glacial history, and one which will be found to bear very directly upon the origin and history of the fauna and flora, especially the origin of the northern fishes, their migrations, spawning periods, the effects of natural barriers and of natural and artificial means of communication. The study of the origin of the life of the Great Lakes is in fact one of the most interesting of general scientific questions.

The significance of the provincial great lake area from the point of view of economic research is indicated both by the extent and value of the commercial fisheries and by the measures already adopted by the Dominion and Provincial Governments for the control of fishery operations and of the practical means of restocking. The annual value of the fisheries is subject to considerable variation, and it is necessary to examine the returns over a long period of years in order to form any real conception as to the possible relations to one another of the number of men engaged, gear, poundage of catch and probable supply. Taking the year 1918 as the last one for which figures for all the provinces including Ontario are available,[1] it is found for this year that the total value of the Ontario fisheries amounted to $3,175,111. As compared with the total for Canada of $60,250,544 this is approximately 5 per cent., a very creditable showing when it is realized that the latter figure includes the value of the Atlantic and Pacific marine fisheries, among the richest in the world. In relation also to the total for the fresh water fisheries of the Dominion, amounting in 1918 to $6,019,005, the Province of Ontario produced of this total an amount equal to 52.7 per cent., while the

[1]Fisheries Statistics, 1918, Dominion Bureau of Statistics, Ottawa, 1920. Cf. also Report of the Department of Game and Fisheries, Ontario, 1918; Toronto, 1919.

great lake fishery of the province alone produced 44 per cent. When it is considered that the Great Lakes are the mainstay of the commercial fishery, that this fishery has been cultivated assiduously for very many years, and that it is first to be considered in all measures of Dominion or provincial legislation, it is evident that there should be available not only detailed information concerning the natural occurrence, migration, growth stages and dimensions, time of maturity, local variations of the spawning period, as well as concerning the natural associations and enemies of every species of direct market value, but also full particulars of all species directly or indirectly serving them as food.

The land-enclosed water areas, though they at least equal, and in all probability greatly exceed the combined areas of the provincial portions of the Great Lakes, are so varied and irregularly distributed with reference to the topography of the country otherwise that they can scarcely be treated as having conditions in common. With the exception of the Lake of the Woods and Rainy Lake, which are boundary waters, they lie wholly within the province. They have a certain facies depending on their respective relations to the underlying substratum and rock formation, which in Ontario shows a marked contrast as between igneous and sedimentary, a contrast enhanced in every way by the extremes of soil formation and other effects of the glacial period. Some of the lakes as purely inland waters are of large size, notably the Lake of the Woods (1,851 square miles) and Nipigon (1,730 square miles), others though much smaller are nevertheless bodies of considerable magnitude, such as Rainy Lake (324 square miles), Nipissing (330 square miles) and Simcoe (300 square miles). Of the thousands of smaller lakes of perhaps less than 100 square miles in extent, some such as the Rideau waters are significant in the early development of the province, others are summer resort lakes of long standing, such as the Muskoka Lakes, while still others, like Lake Timagami are newer game fish areas of which hundreds have been made accessible within recent years through improvements of rail transportation.

Apart from any question of the utilization of the lake areas otherwise, as travel routes or for transportation of timber, the economic factors concerned are chiefly two in number, namely, in what way and to what extent are the lakes in general capable of utilization from the point of view of marketable fishes, and second, what restrictions must be made, or practical means adopted, for increased utilization of the areas for game fishing, considering the great revenue to be derived from the presence in the province of the summer resident and sportsman.

No limnological investigation of these collectively immense areas or indeed of any one of them has hitherto been attempted. Unlike the Great Lakes their waters have not been the object of hydrographic surveys even for determination of depth. Except for ordinary geographical information, what is known about the physical character of the inland waters is chiefly a matter of canals and water power. Though there have been a good many individual investigations dealing with particular groups of plants and animals, much more is known about the whole country from the standpoint of the traveller and sportsman than has been arrived at through scientific study. Every area which as a matter of development is subject to human interference, and this involves the extreme of conditions in areas like the Muskoka Lakes, which are relatively of long standing occupation and therefore of game fish depletion, as opposed to others which with the improvement of means of ready access, always the deciding factor, are now beginning to be occupied, should be thoroughly known from the point of view of the factors entering into the conditions of existence within its limits. The limnological study of such areas, on account of their easy transitions from ponds and puddles to lakes of sufficient magnitude to present typical lacustrine conditions, ought also to yield important data concerning the general stages of lake formation in different situations, and the relation to this development of the groups of aquatic organisms.

No comparative consideration of the annual yield of

marketable fishes coming from the land-enclosed waters of Ontario is worthy of attention which does not first take into account the principles adhered to in framing legislation which would establish the respective spheres of the sportsman interested in game fish waters and the commercial fisherman. Recognizing the Great Lakes as primarily adapted for commercial fishing, and at least some of the inland northern waters as most attractive and eagerly appreciated by the game fisherman, the principle naturally became established in Ontario of the reservation and protection of inland areas from commercial fishing both in respect of sale and the operation of ordinary types of gear. Fortunately in general this principle has been uniformly supported both in Dominion and provincial legislation. A first and very natural exception was made in the case of the Lake of the Woods and related waters, in part because of the predominance as in the Winnipeg area of fishes of a marketable type. A second exception of more recent origin was made in respect of Lake Nipigon and Lake Nipissing, though in general the inclusion of these areas was recognized as requiring close government supervision. On the whole it will be observable both from the small values presented for the commercial fishes and the evidence of large sums of money brought into the country by summer residents and sportsmen that the element of the commercial fishery is only a small part in the total revenue accruing to the province from the existence of the land-enclosed area.

The value of the fisheries of land-enclosed waters of the province was, in 1918, $503,858. This value amounts to about 16 per cent. of the total for Ontario as compared with 84 per cent. for the Great Lakes. Apart from the latter which give a decided advantage to the province, the total value of the fisheries of all land-enclosed waters of the Dominion amounted in 1918 to $3,347,600, of which the corresponding part of Ontario produced only 15 per cent. as compared with Manitoba's contribution amounting to 55 per cent., while Saskatchewan almost equalled Ontario at 13 per cent. Furthermore, of the total for the land-enclosed

areas of Ontario more than half, or $285,169 was produced by the Lake of the Woods and related waters, which, as indicated above, are in a similar position to the Great Lakes as regards the commercial fishes. Lake Nipigon accounts for $128,647, or roughly one fourth, while the balance, amounting to only $90,042 includes the product of Lake Nipissing, valued at $32,294. The sum of the matter is that, excepting some four or more of the principal lakes, the commercial product for the province as regards the inland areas is negligible; the real significance of these areas lies elsewhere.

So far as the economic aspects of the question are concerned the problems to be investigated in connection with the growth of fishes and related matters are exactly of the kind already outlined for the Great Lakes. But, in addition, the existence of a body of water both isolated in relation to other basins, and, because of its circumscribed boundaries, more naturally accessible to the commercial methods of fishing, gives rise to conditions which make the problem of balance and replacement more immediate. If the Great Lakes escaped total depletion before the advent of corrective measures, it was because the spaces were sufficiently vast in relation to the amount and efficiency of the gear employed to give the fishes most sought after some loop-hole of escape. In an enclosed area, even the size of Lake Nipigon, and the matter is more serious the smaller a lake becomes, it is evident that with continued fishing with modern gear, no large species, valuable or not, would have the least chance for survival, if not through the exercise of moderation, protection of small fish to sexual maturity, and practical propagation. More than this, the maintenance of the natural balance of all organisms is a matter of importance, whether as between predacious species and those feeding upon lower organisms, or as between spawn-destroying coarse fishes and others more desirable, or as between the various species of minnows and similar small species and the larger fishes which depend on them for food. In fact an enclosed lake is a small and complete world in itself. Whatever happens in the way of modification of its living contents, practically

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HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
MINNESOTA
LAKE SUPERIOR
WISCONSIN
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
MICHIGAN
NEW YORK
PENNSYLVANIA
ILLINOIS
INDIANA
OHIO
Albany River
Kapiskau River
Abitibi Lake
Timagami Lake
L. Nipissing
Ottawa River
North Channel
GEORGIAN BAY
Muskoka Lakes
L. Simcoe
St. Lawrence River
Rideau L.
Green Bay
St. Clair Lake
Lake of the Woods
Rainy Lake
Lake Nipigon
L. Superior
L. St. Joseph
Severn River
Winisk River
Attawapiskat River
Ekwan River
Moose Riv.
DOMINION HATCHERIES
I Kenora
II Port Authur
III Wiarton
IV Collingwood
V Southampton
VI Sarnia
VII Kingsville
VIII Thurlow
PROVINCIAL HATCHERIES
1 Fort Frances
2 Port Authur
3 Sault Ste Marie
4 Port Carling
5 Mount Pleasant
6 Normandale
PROVINCE OF ONTARIO
SCALE, 140 MILES TO 1 INCH
DISTRIBUTION OF DOMINION & PROVINCIAL HATCHERIES

Map III.

in all cases a matter of human interference, the question of the balance of all organisms, and the balance between the poundage removed and that replaced by natural or artificial means is all important. Doubtless the closer study of conditions would also call into question the advisability of introducing into such area species not adapted either as young or fry to survive, or on the other hand give some point to the introduction of other species whose presence is desirable as marketable or game fishes or even to serve as food for such.

Conservation of the game fishes is quite as much an economic problem as that of the commercial fishes. That it is not usually so recognized is perhaps on the whole a matter of gratification, since it is evident that the protection of game animals and the freedom of the great natural playgrounds are principles which from the beginning have been accepted by legislative authorities. On the other hand no attempt has been made to determine in what respects the invasion of the game country by the tourist and sportsman results in improved circulation of money and prosperity to a larger area, nor to compute what must be a very large amount expended by the non-resident, and contributing to the wealth of the province, if not directly to the provincial treasury through the sale of lands and licenses. It is evident on all hands that the matter of organizing this source of revenue, in a certain sense of capitalizing the natural resources, is one which is being seriously considered elsewhere in America and in Ontario is well worthy of attention. In the game fishes of Ontario we have a wide natural distribution of certain species, notably speckled trout and black bass, and also the occurrence in areas not open to commercial fishing of species, notably lake trout and doré, which deserve to rank as game fishes. The local abundance of these species in the smaller lakes, from most points of view of the game fisherman also the more desirable lakes, is a matter of fundamental importance, since it is the deciding factor, or, if not, a very serious one, in establishing permanency of summer residence. The maintenance of the supply is also immediate

or urgent exactly in proportion as these lakes are frequented. Exact information concerning the complete life histories and the factors bearing upon their success or failure is essential for every occupied area. It is probable too that the communication of such information to the more permanent population would not only contribute to practical sentiment in the matter of conservation but also demonstrate the fact so generally neglected throughout the game country that the protection by the local inhabitants of the game animals is worth to them in money far more than their immediate utilization for food or sale.

Another question with which scientific investigation will ultimately have much to do is that of artificial propagation. Already a hundred years ago, before the settlement of the country was yet solidly established, the better fishes of the Great Lakes were recognized as an important source both of food and profit. By 1850, after a period in which the only restrictions upon the extent of capture were those imposed by primitive means of communication, the effects of excess and wastefulness were already evident. Notwithstanding the better organization of fishing administration from Confederation onwards (cf. Prince '20), by 1880 depletion began to be evident in all the Great Lakes, and questions of replacement became of increasing importance. Artificial propagation owes its inception in Ontario to Samuel Wilmot who began private hatching operations at Newcastle in 1865, and who later as a Dominion officer established the entire hatchery system. The development of this system and the steady increase of the output from year to year[1] has doubtless saved the commercial fishery of the Canadian portions of the Great Lakes from complete destruction. At the present time (cf. Map III) the Dominion system includes eight hatcheries[2] in Ontario, the output of which is supplemented by that of hatcheries established by the

[1]Cf. comparative figures, Fisheries and Game, Report of the Commission of Conservation, Canada, Ottawa, 1911.

[2]Cf. Annual Reports on Fish Culture, Department of Naval Service, Ottawa

Provincial Government to the number of six,[1] while the general supply of the Great Lakes is enormously augmented by the operations of various United States hatcheries under the supervision of the Bureau of Fisheries.

Fish propagation is a technical process, the more difficult because of its aquatic environment, and therefore demanding not only practical ability but also organization of method. The opportunity presented by a spawning period comes only once a year and if lost is irretrievable. The success of a single season's operations depends on controllable elements of precise organization and on uncontrollable factors such as weather, scarcity of spawners, hatchery accidents and the like. If it were possible to effect some organization of scientific work in relation to the hatcheries, an arrangement which would require considerable preparation, a contributory source of information would undoubtedly result which would be analogous in some ways to the usefulness of the agricultural experiment station to the practice of agriculture. Many sides of the hatchery question should be studied by investigators not bound to technical practice, having free time at the proper periods of the year, and provided with equipment adequate to the case; in other words, experimental hatchery work should be carried on with the same kind of equipment as that in regular use, but with additional facilities for scientific study. Bearing in mind that the object of propagation is not simply to make the fisheries hold out a few years longer, but to establish a balance between utilization and replacement, if not indeed an increased output, such as would be the aim of true pisciculture, it is evident that important sources of information are yet unavailable. The case of the hatchery and the commercial fishery is very much that of a mill in which the product is known but the extent or adequacy of the supply is unknown. In order to answer the question it will be necessary to know as nearly as may be practicable the percentage survival of fry and young at different stages and in localities differing both immediately

[1]Cf. Annual Reports, Department of Game and Fisheries, Ontario. Toronto.

and seasonally in respect of their physical characters. It will be necessary to know the true extent of depletion and of artificial increase by corrected figures indicating the poundage of the catch as modified by differences of the total amount of gear and its relative efficiency. There are, however, other considerations.

The recent developments of experimental embryology in relation to the behaviour and growth of aquatic eggs have shown to what extent these features are modified by physical differences in the surrounding medium, the constitution of the medium, absorbed gases and temperature. The investigation of such influences in its bearing upon the development of the eggs of desirable species under hatchery conditions would at least be of great scientific interest and most likely here and there of practical value. The same is true of the study of hybridization, the laws of which, under the influence of the recent work in genetics, are now much more clearly understood. In some of the fresh water fishes, notably *Salmonidae*, there are varietal, racial or environmental modifications which are almost baffling in their complexity, and which should now be thoroughly studied from a genetic point of view under experimental hatchery conditions. Finally the process of re-stocking which involves in part the utilization of young fish or fry, and to which reference has already been made, should be critically examined. While nominally a matter of assisting a natural replacement, the underlying idea is naturally expanded into that of the introduction into depleted waters of the same species from supposedly related waters; in which case it is a question whether the disturbance of the natural balance has not proceeded too far to ensure survival of the introduced stock, also whether as a matter of fact the physical conditions are similar, or if environmental differences are at the moment of introduction beyond the powers of adjustment of the organism. The case is analogous when it is a matter of the introduction of foreign species. Artificial transfer to a hitherto unoccupied area may overcome for the introduced species a natural barrier, permitting it to attain a dominance over

native species perhaps more desirable, or it may readily happen that the desire to introduce a species of recognized merit from elsewhere overcomes the obvious reflection that the new environment is perhaps not suitable in any way, resulting in a process not very different in principle from liberating an infantile south sea islander on the shore of Hudson Bay. One of the recent pronouncements on this point is that of Evermann and Clark ('20, vol. I, p. 279). Concerning Lake Maxinkuckee these authors state:—"Four plants of lake trout aggregating 10,587 fish have been made in this lake. So far as we have been able to learn there is no evidence that any of these survived; there is no authentic record of the capture of a lake trout in this lake. If the physical and biological conditions obtaining in Lake Maxinkuckee had been as well understood before the lake trout were planted, as they are now, those plants would not have been made." The records of failures as well as the sometimes uninformed opposition to hatchery measures should be equally considered and a serious attempt made to bring together all facts and factors, practical and scientific, which bear upon the maintenance of natural balance in every area of economic importance.

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UNIVERSITY OF TORONTO STUDIES

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A STUDY OF THE CISCOES OF LAKE ERIE

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A STUDY OF THE CISCOES* OF LAKE ERIE

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This study was carried out under the auspices of the Biological Board of Canada in response to a request from the Lake Erie Fishermens' Association for an investigation of some of the problems in connection with the cisco fishing industry. In the request it was desired particularly that some information be obtained as to why smaller ciscoes in general are taken in the eastern end of the lake than in the western part.

The major portion of the work having to do with the measurements of the fish and the taking of scales was carried out at various points on Lake Erie during the summer and fall of 1920, but shipments from various points were examined in Toronto during the years of 1919 and 1920.

The author desires to express his appreciation of the assistance given by many fishermen, in particular by Mr. A. E. Crewe, who kindly provided accommodation for the carrying out of the work during the summer of 1920, freely placed all the material of his catches for examination, and gave assistance in many ways. Other gentlemen who facilitated the work in supplying material and in other ways were: Messrs. Charles Ross, Roy Ross, Wilson S. McKillop, A. B. Hoover, C. W. Barwell, R. Kolbe, and W. D. Bates.

Identification of Species

For the separation of the species of shallow water ciscoes (subgenus *Thrissomimus*) as described by Jordan and Evermann† (1911) it appears that three proportional measurements are more or less critical, namely, head in length, depth in length, and depth of caudal peduncle in head. Jordan and Evermann give the following proportions:

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*The word cisco is here used instead of herring for all members of the genus *Leucichthys* except for the tullibees, in accordance with the list of standardized names of North American fish as agreed upon by the U.S. Bureau of Fisheries, the Biological Board of Canada and the Canadian Fisheries Association.

†Jordan, D. S., and Evermann, B. W. 1911. A Review of the Salmonoid Fishes of the Great Lakes with notes on the Whitefishes of other Regions. *Bull. U.S. Bureau Fish.*, Vol. xxix (1909). Document No. 737 (1911).

Species	Head in length	Depth in length	Depth of caudal peduncle in head
L. harengus	4.33	4.3–4.6	3.0
L. sisco huronius	4.66	4.2–4.5	2.9
L. ontariensis	4.5	3.7–4.2	2.66
L. artedi	4.4	3.5–4.0	2.0–2.5
L. eriensis	4.4	3.3–3.5	2.2

Accordingly for each fish examined the necessary measurements were made for the calculation of the above proportions. In addition the girth and the weight were determined and scales removed for age estimation. From June 14 to August 24, 1920, the ciscoes taken in twenty pound nets at the Crewe Bros. Fishery near Merlin were examined daily. In August and November the fish taken at Port Dover, Nanticoke, McKillop's Fishery (near Port Maitland) and Dunnville were examined. The following species have been identified:

(1) *Leucichthys sisco huronius* (J. & E.), Lake Huron cisco.

This species was readily distinguished by the long spindle-shaped body. The average proportions for 60 individuals were as follows: head in length 4.6, depth in length 4.3, depth of caudal peduncle in head 2.95. These figures are practically identical with those given by Jordan and Evermann for Lake Huron. This species is taken rather abundantly in the pound nets at Merlin but very few specimens were seen east of Long Point.

(2) *L. eriensis* (J. & E.). Jumbo cisco.

This is the most abundant species taken in pound nets from Rondeau to Point Pelee. It also occurs in large numbers eastward to Long Point but appears to become very much less abundant beyond. It is noted for the large size attained as compared with the other species of the genus *Leucichthys*. The outstanding characters are (1) the deep body, (2) the more or less pronounced hump at the nape, (3) the deep caudal peduncle, (4) the relatively large scales. The average proportions for 150 individuals were: 4.41, 3.42 and 2.44.

(3) *L. artedi* (Le Sueur). Lake Erie cisco or grayback.

This species occurred in numbers at Merlin next in abundance to *L. eriensis* and appears to occur abundantly throughout the lake. It has been distinguished from the jumbo cisco by (1) the somewhat narrower peduncle, (2) the narrower body with usually little or no hump at the nape, (3) the smaller scales with less of the shiny appearance, (4) the much slower rate of growth as shown in the following table and also later in the discussion of the results of the scale examinations.

L. artedi					*L. eriensis*				
No.	Date	Length cm.	Weight oz.	Age Years	No.	Date Date	Length c.m.	Weight oz.	Age Years
600	July 8	20.7	6	4	234	July 8	20.8	6	3
601		21.8	6	5	235		21.9	7	3
602		21.0	6	5	237		21.1	7	3
603		21.5	6	5	238		22.2	8	3
604		21.0	6	5	239		22.6	8	3
605		22.2	6	6	240		22.8	9	2
606		21.8	6	5	241	July 9	23.7	9	3
607	July 9	22.8	7	6	242		26.5	12	4
609		22.9	7	5	243		21.5	7	3
610		23.4	7	5	244		24.1	10	3

Figure 1 shows a drawing of a scale from specimen No. 606, *L. artedi* and a drawing of a scale from specimen No. 235, *L. eriensis*.

The average proportions for 50 individuals as they occurred at Merlin were 4.26, 3.7 and 2.86. These figures are somewhat different from those given by Jordan and Evermann and may be due in part to the fact that the young of *L. eriensis* are somewhat difficult to separate from this species, and in the selection of the above 50 individuals rather extreme forms were chosen. There is an indication, however, that *L. artedi* is more closely related to the species of the other lakes than perhaps the figures of Jordan and Evermann show.

(4) *L. prognathus* (Smith). Lake Ontario deep water cisco or longjaw.

In both the pound nets and gill nets from Port Dover to Port Maitland a cisco occurs very abundantly whose exact identity and relationships have not been determined as yet. Dr. B. W. Evermann, to whom ten specimens were submitted for identification, refers them provisionally to the species *prognathus* pending further examination of these and additional specimens. The outstanding features of this form are the following: (1) the long mandible which usually projects beyond the upper jaw and in extreme cases almost hooks over it, (2) the relatively long bony snout, (3) the narrow caudal peduncle, (4) the shiny appearance of the scales, (5) the rather deeply forked caudal fin. In a great many individuals the above characters are extreme as well as other features, as indicated by the following proportions, 4.0, 4.2, and 3.2. In other specimens the proportions are about as follows: 4.3, 3.75, and 2.85. The average for 148 individuals is 4.22, 3.88, and 2.85. However, Dr. Evermann states that *L. prognathus* varies greatly. Only a single longjaw was taken at Merlin during

the summer of 1920 on August 24, and it had the proportions 4.1, 3.3, and 2.8. A fisherman at Point Pelee has stated that he recalled having seen during one spring rather large numbers of small longjaws taken in the pound nets in that region. This would indicate a migration occurring during the winter or spring months when temperature conditions would be rather uniform throughout the lake.

The longjaws examined at Dunnville and Port Dover early in November, 1920, were almost ready to spawn. Typically, members of the subgenus *Cisco* (Jordan and Evermann) are said to spawn in late summer but it would not be surprising to find the deep water forms in the shallower, warmer waters of Lake Erie spawning later than those in the other Great Lakes, especially in a mild fall such as occurred in 1920. Two females of *L. johannae* received from Wiarton, Georgian Bay, November 24, 1920, were found not to have spawned.

The following table shows comparative measurements of certain characters of the longjaws in Lake Erie. Measurements are given in decimal fractions of body length.

	PORT MAITLAND						PORT DOVER		
	1032	1042	1037				919	907	918
Head	.26	.25	.25	.245	.25	.24	.23	.23	.24
Depth	.24	.21	.22				.24	.26	.30
C.P. depth	.087	.078	.081	.082	.082	.089	.084	.079	.082
Eye	.054	.058	.060	.06	.06	.055	.066	.055	.065
Snout	.063	.063	.064	.063	.063	.057	.058	.053	.058
Maxillary	.085	.083	.09	.08	.087	.085	.079	.08	.089
Snout to occiput	.17	.17	.17	.17	.17	.16	.166	.15	.173
Gill rakers	45	46	45	41	41	45	45	45	41
Head in length	4.0	4.0	4.0	4.0	4.0	4.1	4.3	4.3	4.1
Depth in length	4.2	4.7	4.6				4.1	3.9	3.3
C.P. depth in head	3.2	3.2	3.2	3.0	3.0	2.7	2.8	3.0	2.9

(5) *L. harengus* (Richardson). Georgian Bay cisco.

A few individuals were taken which agreed in measurements and description with the Georgian Bay cisco. Jordan and Evermann report this species in Lake Erie and no doubt it occurs in small numbers.

For purposes of comparison and for confirmation of the value of proportional measurements, specimens of *L. ontariensis* were obtained from Port Credit on Lake Ontario, and specimens of *L. harengus* from Wiarton and Midland on

Georgian Bay. The average proportions of 20 individuals of *L. ontariensis* were 4.5, 3.8, and 2.6. The average for 25 individuals of *L. harengus* were 4.2, 4.3, and 3.1.

The following table shows the measurements of typical individuals of the various species examined. Measurements are given in decimal fractions of body length.

	[1]*L. harengus*	*L. sisco huronius*	[2]*L. ontariensis*	*L. artedi*	*L. eriensis*	*L. prognathus*
	21	328	3	666	1026	1038
Head	.24	.22	.21	.23	.23	.25
Depth	.21	.22	.26	.26	.33	.24
Caudal peduncle length	.11	.12	.11	.11	.10	.11
Caudal peduncle depth	.073	.074	.084	.085	.095	.081
Eye	.062	.051	.054	.057	.057	.065
Snout	.057	.053	.051	.055	.050	.056
Interorbital space	.068	.064	.062	.068	.067	.065
Maxillary	.079	.074	.066	.081	.073	.086
Snout to occiput	.16	.14	.15	.16	.15	.17
Ventral to pectoral	.31	.36	.35	.36	.36	.33
Pectoral to P-V distance	2.25	2.2	2.4	2.2	2.3	1.9
Pectoral length	.14	.14	.14	.16	.16	.17
Ventral length	.13	.12	.14	.15	.16	.17
Dorsal height	.14	.13	.15	.16	.17	.18
Adipose length	.053	.06	.062	.064	.073	.053
Anal height	.88	.88	.94	.11	.11	.13
Gill rakers	49	47	48	43	46	45
Scales	9-85-8	9-82-8	9-78-8	8-70-7	8-75-7	8-75-7
Head in length	4.2	4.6	4.6	4.3	4.4	4.1
Depth in length	4.7	4.5	3.8	3.5	3.1	4.2
C.P. depth in head	3.2	3.0	2.7	2.8	2.4	3.0

[1]From Georgian Bay. [2]From Lake Ontario.

The following table shows proportions as given by Jordan and Evermann and those obtained for the ciscoes in Lake Erie with the exception of *L. harengus* and *L. ontariensis*.

Species	Jordan and Evermann			Lake Erie		
	Head in length	Depth in length	Depth C.P. in length	Head in length	Depth in length	DepthC.P. in length
L. harengus	4.33	4.3–4.6	3.0	[1]4.2	4.3	3.1
L. sisco huronius	4.66	4.2–4.5	2.9	4.6	4.3	2.95
L. ontariensis	4.5	3.7–4.2	2.66	[2]4.5	3.8	2.6
L. artedi	4.4	3.5–4.0	2.0–2.5	4.26	3.70	2.86
L. eriensis	4.4	3.3–3.5	2.2	4.41	3.42	2.44
L. prognathus	4.0	3.5	3.5	4.22	3.88	2.87

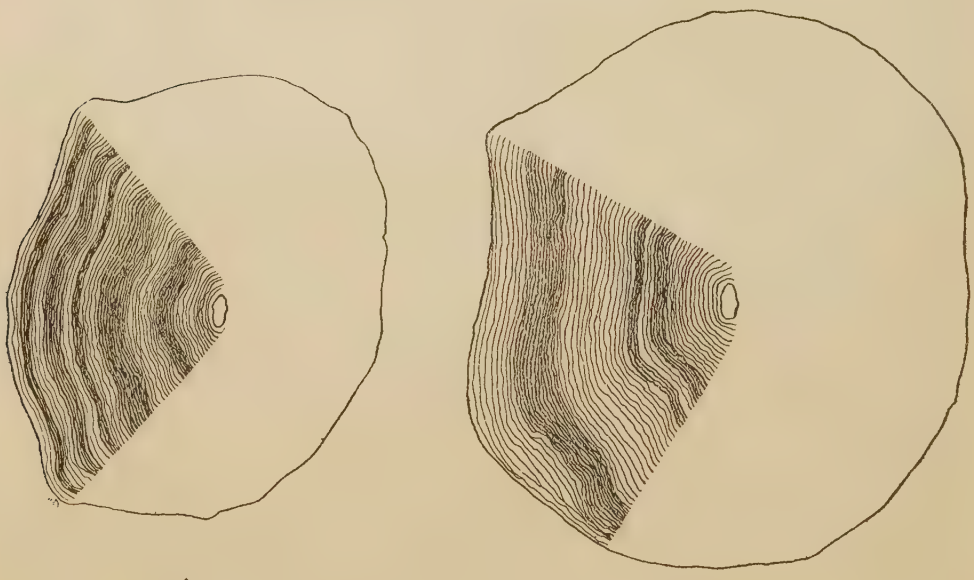

Fig. 1.—Drawings of scales of ciscoes.

A, from specimen No. 606, *L. artedi*, showing 5 winter bands, the fish therefore being in its sixth summer. *B*, from specimen No. 235, *L. eriensis*, showing three winter bands, the fish therefore being in its fourth summer.

[1]From Georgian Bay.

[2]From Lake Ontario.

The scales were used in determining the rates of growth of the various species of ciscoes. The growth areas are usually well marked. Scales from approximately the following number of fish of each species were examined: *L. eriensis*

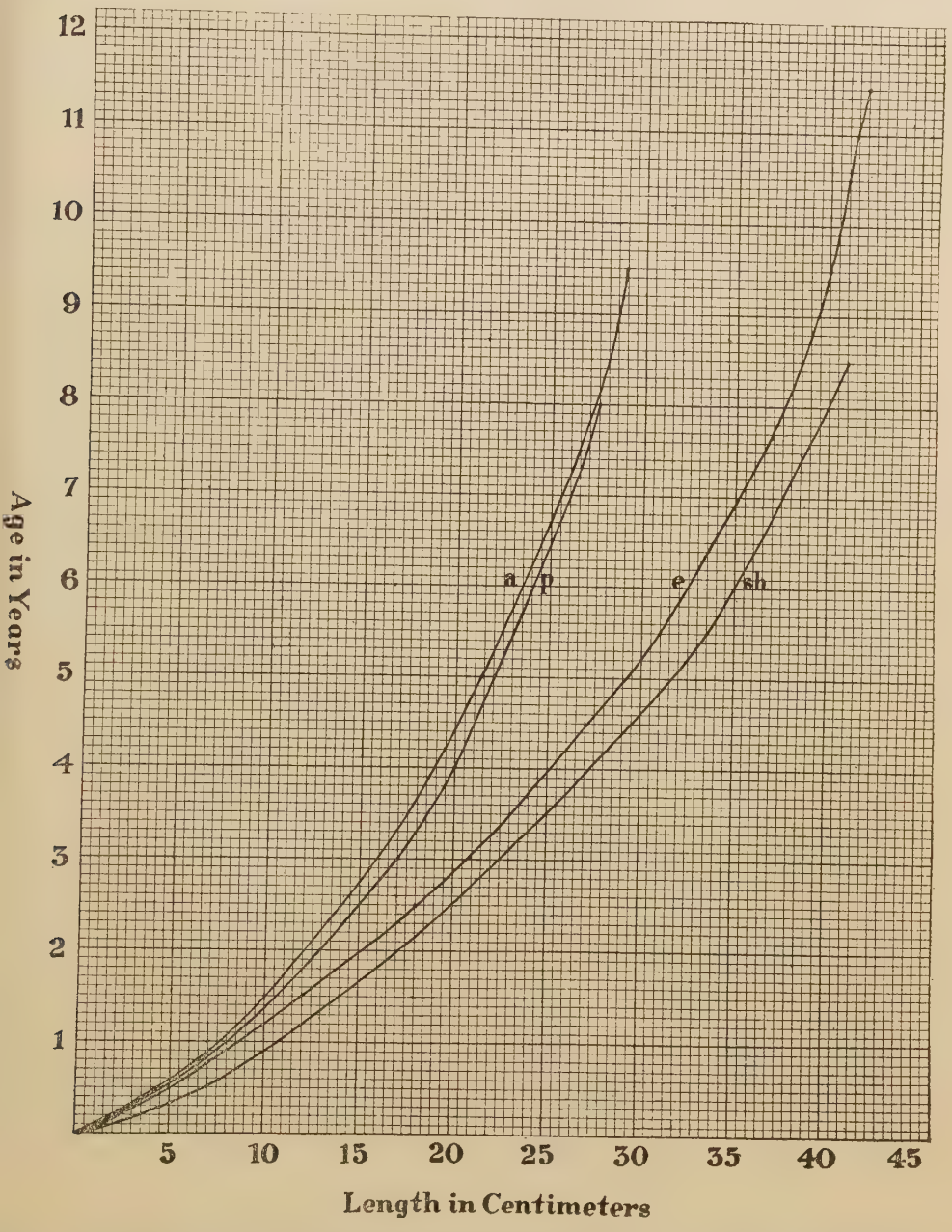

Fig. 2.—Graph illustrating rates of growth of ciscoes in Lake Erie a = *L. artedi*, p = *L. prognathus*, e = *L. eriensis*, sh = *L. sisco huronius*.

140; *L. artedi* 55; *L. sisco huronius* 55; *L. prognathus* 150. The results a shown in Fig. 2. Considerable difficulty was experienced in estimating th rate of growth of *L. sisco huronius*. In the majority of scales some of the winte bands were difficult to distinguish and there was evidence that in some cases a least one winter band was not recorded. It is possible, therefore, that th curve for this species should lie to the left of the curve for *L. eriensis*. Fig. shows the relation of age to weight. The following table gives the data obtaine for the three important commercial species in Lake Erie. The length in centi meters is from the tip of the snout to the base of the caudal fin; the girth jus anterior to the dorsal fin.

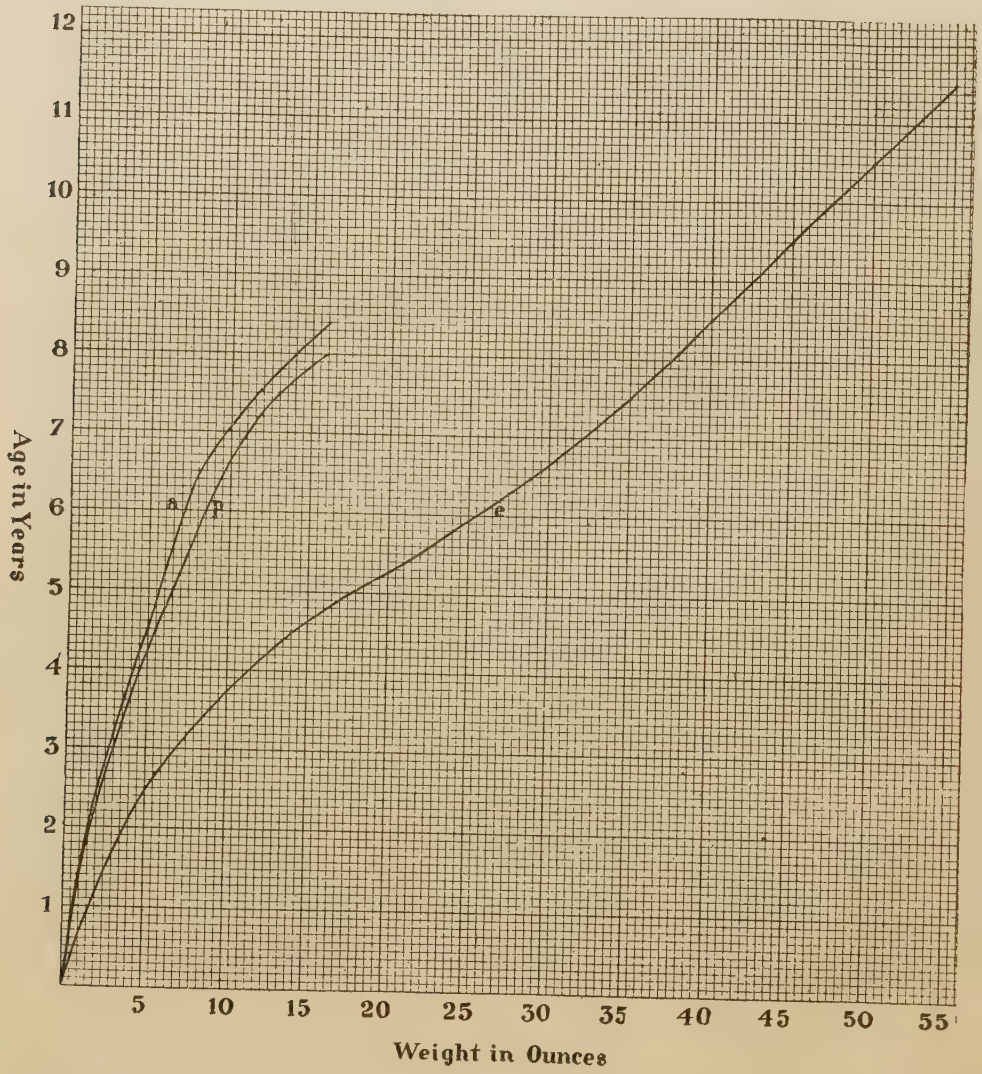

Fig. 3.—Graph illustrating relation of weight to age of ciscoes in Lake Erie. a = *L. artedi*, p = *L. prognathus*, e = *L. eriensis*.

Age	*L. eriensis*				*L. artedi*				*L. prognathus*			
	Length c.m.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.
1	8.5	4.0	1.5	....	7.5	3.0	....	...	8.0	3.0	....	....
2	15.0	6.6	3.5	....	12.5	5.2	....	...	13.0	5.2	....	....
3	20.5	9.1	7.0	6.1	16.0	7.0	3.0	4.5	17.0	7.0	3.0	4.5
4	25	11.4	11.5	7.4	19.0	8.5	4.5	5.2	20.0	8.5	4.5	5.2
5	29	13.3	17.5	8.5	21.5	9.6	5.5	5.8	22	9.8	6.5	5.7
6	32.5	14.8	25.5	9.4	23.5	10.3	7.5	6.3	24	10.7	8.5	6.3
7	35.5	16.0	32.0	10.1	25.5	10.7	9.5	6.7	26	11.4	11.0	...
8	37.5	17.0	37.5	10.8	27.5	11.8	12.5	...	.....	....	.....	...
9	39.5	17.6	42.5	11.3	28.5	....	....	...	....	....	....	...
10	40.5	18	47.5	11.8	....	....	....	...	....	....	....	...
11	41.5	18.5	52.5	...	....	....	....	...	....	....	....	...

The difference in weight between *L. artedi* and *L. prognathus* is partly due to the fact that the specimens of the latter species were examined chiefly in November and the females were then heavy with spawn.

SUMMARY

1. Three species form the bulk of the cisco catch in the Canadian waters of Lake Erie, namely, *L. eriensis*, *L. artedi* and *L. prognathus*.

2. *L. eriensis* is the dominant form westward from Long Point, and *L. prognathus* eastward from Long Point. This statement holds in general, for the former appears to prefer the shallower water while the latter is apparently a deep water form. However their ranges tend to overlap and their migrations at times take them into one another's territory. For example, fishermen have reported occasional schools of longjaws as far west as Point Pelee, and, on the other hand, the jumbo is reported as abundant, at times, off Port Maitland. *L. artedi* occurs abundantly throughout the lake, but probably in greatest numbers west of Long Point.

3. *L. artedi* and *L. prognathus* have rates of growth and increases in weight which are practically identical, while *L. eriensis* increases about 1 1/3 times faster in length and two to three times faster in weight.

4. Examinations of the graphs and tables for rates of growth and increases in weight show that the optimum size for the taking of the jumbo cisco is from the fifth summer upward when they are at least 12 inches in length and 1 pound in weight. Whether the food supply would permit of this as the minimum size it is impossible to say. In regard to *L. artedi* and *L. prognathus* a minimum length of about 10 inches and a weight of about 6 or 7 ounces, when the fish are in their sixth summer, would appear to be quite satisfactory.

5. Concerning the occurrence of smaller ciscoes in the eastern end of the lake, this much can be safely said: that in respect to gill net catches the fishermen in the western portion of the lake secure a larger percentage of jumbo ciscoes and, therefore, get large fish, while the fishermen in the eastern end, particularly off Port Maitland, secure chiefly the smaller species, *L. artedi* and *L. prognathus*. The same facts apply to the pound net catches, with the addition that, since the young inhabit the shallow waters and the shallow water area east of Long Point is more limited, there appears to be a concentration of young ciscoes along the shore, particularly in Long Point Bay, and hence the young are apt to be impounded in large numbers in the pound nets.

6. No data were obtained as to the age when the various species spawn for the first time. Spawning is probably at the end of the third summer, and, if so, the six-ounce regulation protects the two species, *L. artedi* and *L. prognathus* in respect to being allowed to spawn once, but does not protect *L. eriensis* since it attains a weight of six ounces in its third summer.

7. The girth measurements were taken around the body just anterior to the dorsal fin, that is where the greatest girth occurs. The results show that the three inch gill net regulation is quite satisfactory for the species *L. artedi* and *L. prognathus* since they do not attain a girth of six inches until the sixth summer, but barely protects *L. eriensis* since this species attains a girth of six inches in three years.

8. In any undertaking for the artificial propagation of ciscoes in Lake Erie, at least for the region west of Long Point, particular attention should be given to *L. eriensis*, because of its rapid growth and its excellent qualities as a food fish.

CONCLUSION

This study has proved to be merely preliminary. The ciscoes of Lake Erie form a complex association and it has been impossible in this investigation to determine their inter-relations or to study the physical factors in relation to the various forms. Solution of the many difficult problems must await a thorough study of the physical conditions of existence in the various parts of the lake, such as distribution of temperatures, oxygen, carbon dioxide, currents, etc., and the relation of these factors to spawning, growth, movements of the fish, as well as to the production and distribution of their food organisms.

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 3

THE FOOD OF CISCOES (*LEUCICHTHYS*) IN LAKE ERIE

BY

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THE FOOD OF CISCOES (*Leucichthys*) IN LAKE ERIE

By Wilbert A. Clemens,

and

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University of Toronto.

The results of the examination of the contents of the digestive tracts of 211 ciscoes (fresh-water herring) are presented herein. The bulk of the material was obtained early in June, 1919, and from July to November in 1920, from Lake Erie at various points along the north shore. The species examined were *Leucichthys eriensis*, the jumbo cisco; *L. artedi*, the Lake Erie cisco; *L. sisco huronius*, the Lake Huron cisco; and *L. prognathus*, the Lake Ontario deep water cisco (longjaw). These were taken at Merlin, Rondeau, Port Dover, Nanticoke, McKillop's fishery (near Port Maitland), and Dunnville. In addition 19 individuals of *L. harengus*, the Georgian Bay cisco, from Wiarton, Georgian Bay, and 7 individuals of *L. ontariensis*, the Lake Ontario cisco, from Port Credit, Lake Ontario, have been examined for comparative purposes. The material from Merlin, Rondeau, Nanticoke and McKillop's was obtained in pound nets while the material from all the other points was obtained in gill nets.

The results are given in the following tables. In the table "Unidentified species" are placed those fish whose identity was not determined. The figures indicate the relative abundance, namely: (1) that only a few individuals were noted; (2) that the organisms occurred rather abundantly; (3) very abundantly.

SUMMARY.

1. An examination of the tables shows that the ciscoes are pre-eminently plankton feeders. The study practically covers the fishing season, and during that time at least, the free swimming crustacea form the bulk of the food of these fish. Of Canadian waters, Lake Erie produces more ciscoes than all the other Great Lakes combined. For example, in 1919 Lake Erie produced 7,425,713 lbs., while the remainder of the Great Lakes produced 4,022,711 lbs. It is not improbable that the production of ciscoes is directly dependent upon the amount of plankton Crustacea produced. The numbers of these Crustacea which must abound in Lake Erie in order to support the millions of ciscoes, as well as the great numbers of white fish and young of many other species, is almost beyond the imagination. Comparative quantitative plankton studies in the Great Lakes would, no doubt, afford considerable information as to the fish productive capacities of these lakes.

2. It is doubtful if the various species of ciscoes show any preference among the entomostraca as food material. They doubtless take whatever forms occur in the waters they happen to inhabit.

3. In the great majority of alimentary tracts examined, *Daphnia* formed the great bulk of the contents, while other forms were represented by scattered individuals. In many cases *Daphnia* alone were present. This was particularly true of the jumbo and the Lake Ontario ciscoes. It appears, therefore, that *Daphnia* are very much the most important of the entomostraca as food organisms. *Daphnia longispina* occurred in all the material examined, as variety *hyalina galeata*. *Daphnia* ephippia were abundant in October in Lake Ontario and in November in Lake Erie. Occasional ephippia with three eggs were noted.

4. Of the Copepods *Diaptomus sicilis* and *Limnocalanus macrurus* were perhaps the most abundant forms occurring in the digestive tracts, although *Epischura lacustris* occurred frequently and occasionally in considerable numbers. Very often the oil globules of these forms gave the contents a bright red colour.

5. In the eastern end of Lake Erie one of the most important food organisms was *Mysis relicta*. As far as we are aware this is the first record of the occurrence of this form in Lake Erie. Its presence indicates at least an approach of conditions in the eastern end of this lake to conditions in the other Great Lakes.

6. Three individuals were found to have eaten small fish. In each case digestion had proceeded too far to allow of identification. All three ciscoes were taken in the eastern end of the lake, two were longjaws (*L. prognathus*) and the third, while not definitely identified, was probably also a longjaw. A fisherman near Point Pelee has stated that one winter he found that some ciscoes which he took through the ice, had eaten "minnows."

7. As is shown in the table for the longjaws (*L. prognathus*) these fish in June, 1919, had fed practically entirely upon *Ephemeridae* (*Ephemera simulans*), both adults and subimagoes. The importance of these insects as fish food is thus further demonstrated. Moreover, there is no doubt that the transformation of the nymphs to the subimaginal stage takes place at the surface of the water, as occurs in the closely related genus *Hexagenia* (Needham, 1920).* This means that the subimagoes, as well as the imagoes, were taken at the surface of the water by the ciscoes. The projecting lower jaw of these forms is well suited to such surface feeding.

8. The following table, compiled from the food tables, shows the distribution of the food organisms in the lake.

The outstanding points in the table are:

(*a*) The absence of *Mysis relicta* from the western portion and the absence of *Daphnia pulex* and *D. retrocurva* from the eastern portion. Further investigation, however, may show the presence of these species throughout the lake.

(*b*) Although only 43 gill net fish were examined, and the list of forms is, therefore, incomplete, yet the results are an indication of what would be expected in any large body of water, namely, that the shore waters contain a greater number of species of food organisms than the more open waters. The gill net

*Needham, James G. 1920. Burrowing Mayflies of our Larger Lakes and Streams. *Bull. U.S. Bur. Fish.*, Vol. XXXVI, 1917-18.

	Western Portion	Eastern Portion	
	87 pound net fish from Merlin and Rondeau	55 pound net fish from McKillop's and Nanticoke	43 gill net fish from Port Dover and Dunnville
Epischura lacustris	+	+	+
Diaptomus sicilis	+	+	+
Limnocalanus macrurus	+	+	+
Cyclops sp	+	+	
Sida crystallina	+	+	
Diaphanosoma brachyurum	+		
Holopedium gibberum	+		
Daphnia pulex	+		
" *retrocurva*	+		
" *longispina*	+	+	+
Bosmina longirostris	+		+
Eurycercus lamellatus	+		
Chydorus sp	+		
Leptodora kindtii	+	+	
Mysis relicta		+	+
Hyallela knickerbockerii	+		
Ephemeridae	+	+	+
Small fish		+	

fish were taken over 5 miles from shore while the pound net fish were taken within 2 miles of shore.

(*c*) A comparison of the first two columns shows the possibility of there being a greater number of species in the western part of the lake than in the eastern end. There is a possibility also that quantitative differences exist in these regions as well as qualitative.

The results of this study serve to emphasize anew the importance of the plankton fauna of our inland waters, and the necessity for a thorough quantitative, qualitative and distributional investigation of these organisms, including particularly their relations to the production, distribution and movements of fish.

L. ERIENSIS—JUMBO CISCO IN LAKE ERIE.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
118	June 1/19	Rondeau	25.8	13	5	1		1	1	1	3	3						Insect fragments 1.
101	" "	"	27.0	14½	4				1		3	1						
129	" "	"	31.0	21	5						3							*Ephemeridae* 2; *Chironomidae* 1; *Amphipoda* 1.
127	" "	"	35.5	31	6						3							*Epheremidae* 1.
229	July 6/20	Merlin	23.5	8	4				1	2			3					
15 indiv.	" "	"	24.5	10		1	1		1	1			1			3		
15 "	" "	"	24.5	10		1	1		1	1			2			3		
15 "	July 8/20	"	22.5	6½		1	1		1	2	3		2			1		*Diaphanosoma brachyurum* 1; *Holopedium gibberum* 1.
12 "	July 10/20	"	22.5	6½		1	1						1			3		
299	Aug. 2/20	"	26.4	16	4					1			1			3		*Diaphanosoma brachyurum* 1.

1,206	Nov. 12/20	Rondeau	21.3	7		1	1				3								
1,201	" "	"	21.6	6½			1				3								
1,210	" "	"	21.8	7			1				3				1				*Eucercus lamellatus* 1; Crustacean debris 1; *Volvox* 1.
1,213	" "	"	22.2	7½							3								
1,208	" "	"	22.3	8							3								
1,214	" "	"	23.7	10							3								
1,211	" "	"	24.3	11							3								
1,204	" "	"	27.7	17½							3								
1,203	" "	"	33.3	31							3								
	Nov. 24/20	Merlin	24.5				1				3								
	" "	"	26.5			1	2				3								

L. ARTEDI—LAKE ERIE CISCO OR GRAYBACK IN LAKE ERIE

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
104	June 1/19	Rondeau	21.4	5¾	4	2	1		1		2	2						*Hyallela knickerbockerii* I.
807	Nov. 10/20	"	21.6	7½			3	2						1				Crustacean debris 2.
1,027	" "	McKillop's	19.6	4½	4		2	2						2				
1,046	" "	"	20.2	5				3					2					
1,045	" "	"	20.5	5	5			3					2					
1,043	" "	"	20.9	6	5			3						2			1	
666	" 24/20	Merlin	23.5	9	6		1				3					1		

L. SISCO HURONIUS—LAKE HURON CISCO IN LAKE ERIE

Collection Number.	Date.	Locality	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
371	Nov. 24/20	Merlin	26.1	11½							2					3		
1,200	" 12/20	Rondeau	26.3	9							3							

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
17	June 1/19	Nanticoke	17.8	3	4		1							1				*Ephemera simulans* subimagoes 3; Chironomid adults 1
8	" "	"	18.5	3½	4				1									*Ephemera simulans* subimagoes 3.
7	" "	"	19.3	3½	4	1	1		1									" " 3.
10	" "	"	19.5	4	5		1											" " 3; Dipterous adult 1.
42	" "	"	20.8	6	4	1	1		1									*Ephemera simulans* subimagoes 3; Dipterous adult 1.
1	" "	"	20.9	5	5				1									*Ephemera simulans* subimagoes 3; Dipterous adult 1.
16	" "	"	20.9	4½	5				1									*Ephemera simulans* subimagoes 3.
30	" "	"	21.0	5	4		1		1									" " 3.
2	" "	"	21.3	5	5	1	1		1					1				" " 3.

21	June	1/19	Nanticoke	21.4	4¼	6		1		1										"	"	3.
13	"	"	"	21.5	4½	4		1		1										"	"	3.
38	"	"	"	21.8	6	4		1												"	"	3.
6	"	"	"	22.5	4½	6				1					1		1			"	"	3.
120	June	1/19	Rondeau	18.6	4	4	1					3	3									
119	"	"	"	21.3	5	4						3	3									
115	"	"	"	23.4	7½	5	3	1		1		3	3	1								
111	"	"	"	24.6	7	6	1	1				3	3									
716	Nov.	1/20	Dunnville	21.1	8	3	1	1	1					3								
15 indiv.	"	"	"				1	2	1					3								
15 "	"	"	"				2	2	2					3		1				Insect fragments 1.		
837	Nov.	10/20	Nanticoke	20.3	5½	5			3													
843	"	"	"	20.7	5½	5		1	1	1				3						Glochidium.		
834	"	"	"	20.7	5				2					3					1			
845	"	"	"	20.7	5	5													3			
841	"	"	"	20.9	5½	5													3			
817	Nov.	10/20	"	21.5	6	5	1	1	1										2	Crustacean debris 1.		
820	"	"	"	21.8	5	4													3			

L. PROGNATHUS—LAKE ONTARIO DEEP WATER CISCO IN LAKE ERIE—Cont.

Collection Number.	Date.	Locality.	Length in cms.	Weight in os.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops sp.*	*Sida crystallina.*	*Daphnia pulex*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
829	Nov. 10/20	Nanticoke	23.0	7	4													Small fish fragments
816	" "	"	23.0	7½	6			1									3	
826	" "	"	23.2	6½	5			2						1			1	Small fish fragments.
808	" "	"	25.4	9½	6		1						2				2	
1,051	Nov. 10/20	McKillop's	21.4	5½	5		1										3	
1,044	" "	"	21.5	5	5		1	1					2				3	
1.039	" "	"	22.0	5½	5												3	
1,032	" "	"	22.3	5½	5												3	

L. HARENGUS—GEORGIAN BAY CISCO IN GEORGIAN BAY.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
23	Nov. 24/20	Wiarton	19.1	3¾	4		3	2					2					
25	" "	"	22.4	6	5	1	2	2					2					
21	" "	"	22.7	5½	6		2	2						2	1			Ostracods 1.
27	" "	"	23.4	7	6	1	2	2					1				1	
15 indiv.	" "	"	simi	lar		1	2	2	1				1		1			

L. ONTARIENSIS—LAKE ONTARIO CISCO IN LAKE ONTARIO

Collection Number.	Date.	Locality.	Length in cms.	Weight in oz.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longiostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
2	Oct. 21/20	Port Credit	22.0	7½	3								3					
7	" "	"	22.7	8	3		1						3					
6	" "	"	23.9	9¼	3								3					
1	" "	"	24.5	9½	4								3					
5	" "	"	25.9	10½	4								3					

L. PROGNATHUS?—LAKE ONTARIO LONGJAW IN LAKE ONTARIO

11	Nov. 25/20	Port Credit	22.6	8	3						3							
9	" "	"	26.4	12½	4												3	

123	June	1/19	Rondeau	19.9	4¼	4					1	3	3						
107	"	"	"	23.8	8	4	2	1		1		3	3				1		Hydrachnid 1.
15 indiv.	Aug.	5/20	Nanticoke				2		2	1	1			2			1		Insect fragments (*Chironomidae, Trichoptera Ephemeridae*) 3.
1 "	"	9/20	McKillop's																*Ephemeridae* (*Ephemera, Heptagenia*, imagoes and subimagoes) 3.
12 "	Nov.	3/20	Port Dover															3	Insect fragments 1.
809	"	10/20	Nanticoke	21.1	6	4												3	
830	"	"	"	22.9	7	5									1			3	
810	"	"	"	23.2	11	7		2										2	Small fish.
824	"	"	"	21.0	6	5		1	1										Crustacean debris 3.
812	"	"	"	23.5	9½	6	2	3	2						1				
819	"	"	"	23.6	11	4		1										3	
1,048	"	"	McKillop's	24.3	11										1			3	
1,212	Nov.	12/20	Rondeau	23.5	11							3							*Chydorus* sp.? 1.
1,207	"	"	"	26.2	11½			1				3							

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 4

A PROVISIONAL LIST OF THE FISHES OF LAKE ERIE

BY

JOHN R. DYMOND

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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1922

A PROVISIONAL LIST OF THE FISHES OF LAKE ERIE

Considering the value of its fisheries, surprisingly little systematic study has been devoted to the fishes of Lake Erie. Our knowledge of the species occurring in the lake appears to have been gained incidentally in connection with investigations on some of the species of commercial importance and through surveys of neighbouring areas.

Although Lake Erie is one of the most productive fishing grounds in the world, its productivity could no doubt be increased by proper management. Investigations with this object in view have been made from time to time, but for the most part these investigations have been confined to the species whose numbers it was desired to increase. No study of the problem as it affects the lake as a whole has yet been undertaken. When such a study comes to be made, information as to the species that occur in the lake, their distribution and relative prevalence will be of fundamental importance. The present list is intended to be a contribution towards such a study. It at least indicates how unsatisfactory is our present knowledge of the fish fauna of the lake, especially in Canadian waters.

The list contains 91 species of fish and two species of lamprey. No species is included which has not been authentically recorded from Lake Erie. Except in the case of commercial species or those recorded in official reports, the authority for including it is given in the case of each species. Brief reference has also been made to the general range or habitat of the less common species found in the lake.

In the preparation of this list, the publication "Fishes of Ohio", Osburn ('01), has been found to be of great assistance. It includes not only the results of his own observations, but

also those of Rafinesque, Kirtland, Jordan, Henshall and others. Many species not elsewhere recorded for the lake are included as a result of Osburn's observations in Sandusky bay in the summers of 1899 and 1900. I am also indebted to Professor Osburn for the identification of several specimens of *Cyprinidae* and of *Cottus ictalops* reported herein.

Other lists consulted contain only occasional references to the occurrence of species in Lake Erie. The expression "Great Lakes Region", often met with in describing the range of species, is unsatisfactory for the preparation of a list such as the present one. Even where a species is said to occur "in the Great Lakes", the reference is hardly less unsatisfactory, for the fauna of each of the lakes exhibits peculiarities of its own. Among the works consulted the following were found to be of most value: Jordan and Evermann ('96), Forbes and Richardson ('08), Bean ('03), and Nash ('08). Many other publications have been consulted but only those containing definite reference to the occurrence of species in Lake Erie are included in the list of literature cited.

The basis of the present list was obtained by reference to two collections from Lake Erie made during the summer of 1920, one by Dr. W. A. Clemens, University of Toronto, and the other by a party from the Royal Ontario Museum of Zoology. Dr. Clemens concerned himself principally with the ciscoes (lake herrings) but he secured specimens of all the species brought in by the fishermen. Most of his specimens, other than ciscoes, were taken at Merlin, Ontario.

The Museum party was stationed at Point Pelee. Their primary object was to secure typical specimens of some of the chief commercial species from which to make casts and colour sketches for permanent museum exhibition specimens. Their specimens were also secured from fishermen.

The species secured by Dr. Clemens were *Ichthyomyzon concolor*, *Acipenser rubicundus*, *Lepisosteus osseus*, *Amia calva*, *Ictalurus punctatus*, *Ameiurus nebulosus*, *Catostomus commersonii*, *Cyprinus carpio*, *Notropis rubrifrons*, *Hybopsis*

storerianus, Hiodon tergisus, Dorosoma cepedianum, Coregonus albus, Leucichthys harengus, Leucichthys sisco huronius, Leucichthys artedi, Leucichthys eriensis, Leucichthys prognathus, Lucius lucius, Pomoxis sparoides, Ambloplites rupestris, Lepomis pallidus, Eupomotis gibbosus, Micropterus salmoides, Stizostedion vitreum, Stizostedion canadense griseum, Perca flavescens, Percina caprodes zebra, Roccus chrysops, Aplodinotus grunniens, Lota maculosa.

The collection made by the Royal Ontario Museum of Zoology party included *Ichthyomyzon concolor, Lepisosteus osseus, Ictalurus punctatus, Ameiurus natalis, Ameiurus nebulosus, Noturus flavus, Catostomus commersonii, Hybopsis storerianus, Hiodon tergisus, Coregonus albus, Pomoxis sparoides, Stizostedion vitreum, Stizostedion canadense griseum, Roccus chrysops, Aplodinotus grunniens.*

During the spring and summer of 1921 a number of Lake Erie fishermen preserved for the Department of Biology specimens of the fish taken in their nets, especially the less common species. Mr. A. E. Crewe, of Merlin, Ontario, sent *Ichthyomyzon concolor, Petromyzon marinus unicolor, Notropis rubrifrons, Hybopsis storerianus,* and *Cottus ictalops.* Mr. W. D. Bates, of Ridgetown, Ontario, sent the following taken at Rondeau, Lake Erie: *Ichthyomyzon concolor, Catostomus commersonii, Moxostoma breviceps, Moxostoma aureolum, Hybopsis storerianus, Coregonus albus, Salmo gairdneri, Pomoxis sparoides, Stizostedion vitreum, Perca flavescens, Roccus chrysops.* From Mr. A. B. Hoover, of Nanticoke, Ontario, were received *Carpiodes thompsoni, Catostomus commersonii, Moxostoma breviceps, Notropis rubrifrons, Hybopsis storerianus, Hiodon tergisus, Dorosoma cepedianum, Percopsis guttatus, Pomoxis sparoides, Ambloplites rupestris.*

The abbreviations used in the following pages refer uniformly to the following authorities:—

Osburn ('01)	"Fishes of Ohio"
J. & E., Bull. 47 ('96)	"The Fishes of North and Middle America."
Jordan & Evermann ('08)	"American Food and Game Fishes."

Jordan ('82)	"Report on the Fishes of Ohio."
Forbes & Richardson ('08)	"The Fishes of Illinois."
Bean ('03)	"Catalogue of the Fishes of New York."
Nash ('08)	"Vertebrates of Ontario."
Clemens	The collection made by Dr. W. A. Clemens from Lake Erie during the summer of 1920.
R.O.M.Z. Party	The collection made by a party from the Royal Ontario Museum of Zoology stationed at Point Pelee during the summer of 1920.
Crewe	The collection received from Mr. A. E. Crewe as mentioned above.
Bates	The collection received from Mr. W. D. Bates as mentioned above.
Hoover	The collection received from Mr. A. B. Hoover as mentioned above.

The nomenclature adopted is that of Jordan and Evermann ('96) except in the case of Coregonus and Leucicthys, for which their later publication ('11) "Review of the Salmonoid Fishes of the Great Lakes" has been followed.

ANNOTATED LIST OF SPECIES

Ichthyomyzon concolor (Kirtland). Silvery Lamprey

The only species of lamprey previously recorded from Lake Erie. Specimens secured by Clemens and R.O.M.Z. party in 1920, and by Crewe and Bates in 1921. Also recorded by Huntsman ('17) from Lake Erie.

Petromyzon marinus unicolor (De Kay). Lake Lamprey

A specimen, 21 inches long, was taken on November 8th, 1921 in Lake Erie at Merlin, Ontario by Mr. A. E. Crewe.

Polyodon spathula (Walbaum). Paddle-fish

"A single example has been recorded from Lake Erie which it doubtless reached through the Wabash and Erie canal" Jordan and Evermann ('08). Common in the larger streams of the Mississippi valley.

Acipenser rubicundus Le Sueur. Lake Sturgeon

Less abundant than formerly but still of considerable commercial importance.

Lepisosteus osseus (L.).[1] Common Gar Pike

Common.

Lepisosteus platostomus Rafinesque. Short-nosed Gar Pike

Rare. "Sandusky bay, one specimen" Osburn ('01). The specimen described by Bean ('03) is No. 3241 U.S. Nat'l Mus. from Cleveland. Common throughout the Mississippi valley.

Amia calva L..[1] Bowfin; Dogfish

Common. Of little or no value as a food fish.

Ictalurus punctatus (Rafinesque). Spotted Catfish

Taken in larger numbers than any other catfish by the fishermen on the Canadian side of the lake, at least at Merlin and Point Pelee. "Taken most frequently [in our waters] in Lakes Erie and Ontario" Nash ('08). Taken by Clemens and R.O.M.Z. party, 1920. Ranges south through the Mississippi valley and north at least as far as Winnipeg.

Ameiurus lacustris (Walbaum). Great Lake Catfish

"Generally distributed throughout the Great Lakes and in deep rivers, but is more abundant in Lake Erie than any other of our waters" Nash ('08).

Ameiurus natalis (Le Sueur). Yellow Catfish

"In Lakes Ontario, Erie and Huron" Nash ('08). Commonly taken in the nets off Point Pelee (R.O.M.Z. party).

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[1] "The time will doubtless come when thoroughgoing measures will be taken to keep down to the lowest practicable limit the dogfish and the gars—as useless and destructive in our productive waters as wolves and foxes formerly were in our pastures and poultry-yards." Forbes and Richardson ('08).

Ameiurus vulgaris (Thompson). Long-jawed Catfish

"Taken in Lake Erie" Jordan ('82). "Occasionally taken in the Ohio river, but is more abundant in Lake Erie" Bean ('03). "Lower jaw more or less projecting; in other respects scarcely distinct from *A. nebulosus*, with which it may intergrade" J. & E. Bull. 47 ('96).

Ameiurus nebulosus (Le Sueur). Common Bullhead

Commonly taken by fishermen at Merlin (Clemens) and at Point Pelee (R.O.M.Z. party). Said by Bean ('03) to be the most abundant catfish in Lake Erie and its tributaries.

Ameiurus melas (Rafinesque). Black Bullhead

"Sandusky bay at Black Channel" Osburn ('01). "Generally speaking, it is not distributed so far to the northward or eastward as our other abundant bullheads . . . . . through the Great Lakes of Ontario, Erie and Michigan" Forbes and Richardson ('08). "Variable, much resembles *A. nebulosus* but smaller, with shorter, deeper anal and especially shorter pectoral spines" J. &. E. Bull. 47 ('96).

Leptops olivaris (Rafinesque). Mud Cat

Osburn ('01) quotes McCormick of 1892 as follows, referring to the occurrence of this species in Lake Erie, "Quite rare; I have seen but one specimen fresh, though I have noticed heads on the beach." A fish of the Mississippi valley and Gulf States.

Noturus flavus Rafinesque. Stone Cat

"Lake Erie at Sandusky, frequently thrown up dead on the beach by the waves; not noticed in Sandusky bay" Osburn ('01). Secured at Point Pelee by R.O.M.Z. party.

Schilbeodes gyrinus (Mitchill). Tadpole Stone Cat

Osburn ('01) reports having observed it to be common among decaying vegetation in shallow water in Sandusky bay in 1896.

Schilbeodes miurus (Jordan). Mad Tom

"Sandusky bay" Osburn ('01).

Carpiodes thompsoni Agassiz. Drum; Lake Carp

"Lake Erie at Toledo" J. & E. Bull. 47 ('96). "Common in Lake Erie" Nash ('08). Taken by Hoover, 1921.

Catostomus catostomus (Forster). Northern Sucker

"Quite abundant in Lake Erie" Jordan ('82). "Occurs in the Great Lakes and northwest to Alaska in clear, cold waters. It is very common in Lake Erie" Bean ('03).

Catostomus commersonii (Lacépède). Common Sucker

Common at Merlin (Clemens) and Point Pelee (R.O.M.Z. party). Bates and Hoover collections, 1921. "Most abundant of all the suckers in Ontario waters" Nash ('08). Osburn ('01) speaks of it as "one of the commonest species", in Ohio.

Catostomus nigricans Le Sueur. Hog Sucker

Said by Nash ('08) to be found in Lake Erie.

Erimyzon sucetta oblongus (Mitchill). Chub Sucker

"Sandusky bay" Osburn ('01). "Great Lakes region to Maine and the Dakotas, south to Virginia . . . . . gradually passing southward into the typical *sucetta*" J. & E. Bull. 47 ('96).

Minytrema melanops (Rafinesque). Striped Sucker

"Found in the Great Lakes and south . . . . In Pennsylvania it is limited to Lake Erie and the Ohio valley" Bean ('03). Reported from Lake Erie by Nash ('08).

Moxostoma anisurum (Rafinesque). White-nosed Sucker

Reported by Jordan ('82) from Lake Erie as *M. carpio*. "Great Lakes region; not very common, but widely distributed" J. & E. Bull. 47 ('96).

Moxostoma aureolum (Le Sueur).[1] Common Mullet; Redhorse

"Sandusky bay" Osburn ('01). "Inhabits the Great Lakes and the region northward . . . . common in Lake Erie" Bean ('03). "Formerly abundant in the waters of the Lakes from the St. Lawrence to Lake Superior, but owing to persistent netting during the spawning season it has become comparatively scarce" Nash ('08). Taken by Bates, 1921.

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[1] "Until very recent years this has been recorded as two species, the short-headed, small-mouthed form as *M. aureolum*; and the more ordinary form as *M. macrolepidotum duquesnii* (Le Sueur). This matter is cleared up by Jordan and Evermann (Bull. 47, U. S. Nat. Mus.). It is very probable that some collectors have confused the short-headed form with *M. breviceps* (Cope)." Osburn ('01).

Moxostoma breviceps (Cope). Short-headed Mullet

"Abundant in Lake Erie" J. & E. Bull. 47 ('96). "Seems to be confined entirely to Lake Erie so far as our province is concerned" Nash ('08). Taken by Bates and Hoover, 1921.

Placopharynx duquesnii (Le Sueur)

Osburn ('01) quotes McCormick of 1892 as follows, "Lake Erie, common with other mullets". A southern species.

Cyprinus carpio L. Carp

Very abundant, especially at Rondeau.

Carassius auratus (L.). Goldfish

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie. Reported by fishermen at Point Pelee, Ontario, but no specimen taken.

Pimephales notatus (Rafinesque). Blunt-nosed Minnow

"Sandusky bay" Osburn ('01). Forbes and Richardson ('08) say this species seems to find a satisfactory place of residence in streams of any size or lakes or ponds of any description.

Semotilus atromaculatus (Mitchill). Creek Chub

Essentially a creek species but recorded by Osburn ('01) from Sandusky bay.

Leuciscus elongatus (Kirtland). Red-sided Shiner

"Generally speaking, a brook species . . . . . though Dr. Kirtland, who described the species, records it from Lake Erie" Osburn ('01).

Opsopœodus emiliæ Hay

"Lake Erie" J. & E. Bull. 47 ('96). Southern in general range.

Abramis crysoleucas (Mitchill). Golden Shiner

Sandusky bay" Osburn ('01). Frequents sluggish waters.

Notropis anogenus Forbes

Taken at Put-in-Bay by Ward ('19) in connection with a study of fish parasites.

Notropis cayuga Meek

Osburn ('01) reports it as common in Sandusky bay.

Notropis heterodon (Cope)

"Sandusky bay" Osburn ('01).

Notropis blennius (Girard). Straw-coloured Minnow

"Sandusky bay" Osburn ('01).

Notropis hudsonius (DeWitt Clinton). Spawn-eater; Spot-tailed Minnow; Smelt

"Lake Erie, near Sandusky, abundant" Osburn ('01). "Abundant in the Great Lakes" J. & E. Bull. 47 ('96). "Abundant in the Great Lakes and at the mouths of the rivers opening into them" Forbes and Richardson ('08). Essentially a minnow of the larger rivers and lakes.

Notropis whipplii (Girard). Silver-fin

"Sandusky bay" Osburn ('01). Characteristically a minnow of clear streams.

Notropis cornutus (Mitchill). Shiner; Dace

"Sandusky bay" Osburn ('01). "Almost everywhere the most abundant fish in small streams" J. & E. Bull. 47 ('96).

Notropis atherinoides Rafinesque

"Exceedingly common in Lake Erie" Jordan ('82). "Through the Great Lakes . . . . It moves and feeds in large schools, thousands being frequently seen together near the surface" Forbes and Richardson ('08).

Notropis rubrifrons (Cope). Rosy-faced Minnow

"Sandusky bay and Lake Erie at Sandusky" Osburn ('01). Secured by Clemens at Merlin, 1920; also by Crewe and Hoover, 1921. "Delights in the clear waters of rapid streams" Forbes and Richardson ('08).

Rhinichthys cataractæ (Cuvier & Valenciennes). Long-nosed Dace

Although fond of clear, swift waters, Jordan ('82) reports it as found in the tributaries of Lake Erie and even in the lake itself.

Hybopsis dissimilis (Kirtland). Spotted Shiner

"Lake Erie" J. & E. Bull. 47 ('96). Great Lakes region, west and south.

Hybopsis storerianus (Kirtland). Lake Minnow

"Abundant in Lake Erie" Jordan ('82). "Lake Erie near Sandusky" Osburn ('01). Common at Merlin (Clemens) and Point Pelee (R.O.M.Z. party) 1920. Taken by Crewe,

Bates and Hoover, 1921. "Lake Erie to Nebraska . . . abundant in the larger streams, especially in Iowa" J. & E. Bull. 47 ('96).

Anguilla chrysypa Rafinesque. American Eel

"According to Kirtland the eel did not formerly inhabit the Lake Erie drainage, but if not, it has found its way there through the canals" Osburn ('01).

Hiodon tergisus Le Sueur. Moon-eye

Taken in considerable numbers in the fishermen's nets. Of little commercial importance. Clemens and R.O.M.Z. party, 1920. Hoover, 1921. "Great Lakes and the Mississippi valley; north to Assiniboine river" J. & E. Bull. 47 ('96).

Dorosoma cepedianum (Le Sueur). Gizzard Shad

Common. "Cape Cod to Mexico; abundant southward . . . . . permanently resident (var. *heterurum*) everywhere in the Mississippi valley in the larger streams; also introduced into Lake Michigan and Lake Erie" J. & E. Bull. 47 ('96). Clemens, 1920. Hoover, 1921.

Pomolobus chrysochloris Rafinesque. Blue Herring; Sawbelly

Originally confined to the Gulf of Mexico and Mississippi valley. "Introduced through the canals into Lake Erie and Lake Michigan" J. & E. Bull. 47 ('96).

Coregonus albus Le Sueur. Lake Erie Whitefish

"This species is the common whitefish of Lake Erie. It is very close to *Coregonus clupeaformis*, the whitefish of the other lakes, differing only in form and colour. Compared with the latter, the Erie whitefish has a smaller head, higher nape, more angular form, and the colour is almost pure olive-white, without dark shades or dark stripes along the back. The flesh is softer, containing more fat. All these differences may be correlated with the fact that Lake Erie is shallow, and its southern shore is fed by warm, shallow, muddy, or milky rivers" Jordan & Evermann ('11).

Leucichthys harengus (Richardson). Georgian Bay Cisco

Clemens ('22) records this species as occurring sparingly in Lake Erie.

Leucichthys cisco huronius (J. & E.). Lake Huron Cisco

"Occasionally enters Lake Erie" Jordan & Evermann ('11). Clemens ('22) found it fairly abundant especially in western portion of the lake.

Leucichthys artedi (Le Sueur). Lake Erie Cisco

"Abounds in Lake Erie especially in its southern parts" Jordan & Evermann ('11). Clemens ('22) reports it as abundant in Canadian waters.

Leucichthys eriensis (J. & E.). Jumbo Cisco

"Inhabits especially the north shore of Lake Erie, where it is extremely abundant" Jordan & Evermann ('11). Clemens ('22) found it very abundant, particularly west of Long Point. On account of its great abundance, size and quality, the most important cisco of Lake Erie.

Leucichthys prognathus (Smith). Lake Ontario Cisco; Long-jaw

Clemens ('22) found this species very abundant east of Long Point. Typically inhabits the deep water of the eastern end of the lake.

Leucichthys macropterus Bean

A specimen remarkable for the development of its fins has been described by Bean ('16) as *L. macropterus*.

Salmo gairdneri Richardson. Steelhead Trout

A specimen was taken at Rondeau, Lake Erie, on July 6, 1921, by Mr. W. D. Bates, of Ridgetown, Ontario. This species is propagated by the U.S. Fish Commission and has been introduced into Lake Superior.

Cristivomer namaycush (Walbaum). Great Lake Trout

The Annual Reports of the Department of Game and Fisheries, Province of Ontario, show that approximately two thousand pounds are taken annually from the Canadian waters of Lake Erie. It is found more especially at the eastern end of the lake.

Umbra limi (Kirtland). Mud Minnow

Osburn ('01) found it abundant in the "Black Channel" in Sandusky bay. Usually met with in ponds and creeks with a soft muddy bottom.

Lucius vermiculatus (Le Sueur). Little Pickerel

Taken by Osburn ('01) in Sandusky bay. An inhabitant of the Ohio and Mississippi rivers and streams flowing into Lake Erie and Lake Michigan from the south.

Lucius lucius (L.). Common Pike

Still of considerable commercial importance in Lake Erie, although less abundant than formerly. A cosmopolitan species of the northern hemisphere.

Lucius masquinongy (Mitchill). Maskinonge

Nash ('08) gives the range of this species in Ontario as follows: "In the St. Lawrence about the Thousand Islands, in the waters of the Trent valley, Lake Scugog, Lake Simcoe, and many of our inland lakes, but I have no record of its occurrence in any of the Great Lakes except Lake Erie and the Georgian Bay, where it is quite common."

Fundulus diaphanus menona (Jordan & Copeland). Killifish

Osburn ('01) found it common in Sandusky bay.

Eucalia inconstans (Kirtland). Brook Stickleback

"The Great Lakes from Ontario to Superior" Forbes and Richardson ('08).

Percopsis guttatus Agassiz. Trout Perch

According to Osburn ('01), McCormick of 1892 found this species to be common in Lake Erie. Forbes and Richardson ('08) report it as common in the Great Lakes but rare south of them. Nash ('08) says it ranges all through the Great Lakes and their tributaries north to Hudson Bay. Hoover took it at Nanticoke, 1921.

Aphredoderus sayanus (Gilliams). Pirate Perch

Reported for Lake Erie by Osburn ('01) on the authority of Henshall in 1889. "Occurs in Lake Erie" Bean ('03). "Through the Great Lakes at least as far east as Lake Erie" Forbes and Richardson ('08). Apparently confined to the Great Lakes and southward.

Labidesthes sicculus Cope. Silversides

"Very abundant on sandy bottom in shallow water in Sandusky bay" Osburn ('01). "Found in Lake Ontario,

Lake Erie and the Detroit river" Nash ('08). "In all the Great Lakes" Forbes and Richardson ('08). A species of southern distribution.

Pomoxis annularis Rafinesque.[1] Crappie

Jordan ('82) reports it as rarely taken in Lake Erie. "Occurs rarely in Lake Erie" Nash ('08).

Pomoxis sparoides (Lacépède). Calico Bass

"In the Great Lakes in large numbers" Jordan ('82). Taken in 1920 at Point Pelee (R.O.M.Z. party) and at Merlin (Clemens). Bates and Hoover, 1921. See footnote under preceding species.

Ambloplites rupestris (Rafinesque). Rock Bass

"Sandusky bay" Osburn ('01). Forbes and Richardson ('08) state that this species has been taken from Lakes Huron, Erie and Ontario, but that it lives by preference in clear waters flowing over a rock bottom. Clemens, 1920. Hoover, 1921.

Chænobryttus gulosus (Cuvier & Valenciennes). Warmouth

"Lakes Michigan and Erie seem to mark its most northerly distribution . . . . everywhere a fish of the bayous, mud-bottomed ponds, and lakes, and lowland streams" Forbes and Richardson ('08).

Lepomis megalotis (Rafinesque). Long-eared Sunfish

"Sandusky bay" Osburn ('01). "In Lakes Erie, Huron and Michigan" Forbes and Richardson ('08). Abundant southward.

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[1] "It is worthy of note that in Chippewa Lake, which drains into the Ohio river system, this species (*P. annularis*) was found exceedingly abundant, but none of the next species (*P. sparoides*) were taken, while in Summit Lake, with very similar surroundings, but draining into Lake Erie, only *P. sparoides* was taken. These lakes are but a short distance apart, the former being near Medina, the latter at Akron." Osburn ('01).

"A tendency to geographical separation is shown by the fact that *annularis* is the more abundant southward . . . . and *sparoides* northward—the latter, indeed, also ranging somewhat the farther to the north." Forbes and Richardson ('08).

Lepomis pallidus (Mitchill). Blue Sunfish

"Very abundant in Sandusky bay" Osburn ('01)." Occurs abundantly in some parts of Lakes Ontario and Erie" Nash ('08). "In the Great Lakes from Ontario westward, ranging thence to the south and west" Forbes and Richardson ('08). Taken by Clemens at Merlin, 1920. Jordan and Evermann ('08) say that it is *the* sunfish of the lakes, whether large or small, but it is decidedly more abundant in the smaller ones.

Eupomotis gibbosus (L.). Pumpkin Seed

"In Sandusky bay . . . . it is the most abundant sunfish" Osburn ('01). "In Lakes Huron, Erie, Ontario and Champlain" Forbes and Richardson ('08). Clemens took it at Merlin, 1920.

Micropterus dolomieu Lacépède. Small-mouthed Black Bass

"Sandusky bay" Osburn ('01). Less common in Lake Erie than the next species. Prefers running water.

Micropterus salmoides (Lacépède). Large-mouthed Black Bass

"Sandusky bay" Osburn ('01). Clemens took it at Merlin, 1920. "Prefers lakes, bayous and other sluggish waters" Jordan and Evermann ('08).

Stizostedion vitreum (Mitchill). Pike Perch

Very abundant and of great commercial importance. Three colour phases occur and have received distinctive vernacular names, viz. gray pickerel, yellow pickerel and blue pickerel. The significance of these colour phases is not understood.

Stizostedion canadense griseum (DeKay). Sauger

Abundant in Lake Erie; of much less commercial importance than *S. vitreum*.

Perca flavescens (Mitchill). Yellow Perch

Very abundant. One of the most important commercial species in the lake.

Percina caprodes (Rafinesque). Log Perch

"Lake Erie at Sandusky" Osburn ('01). To the northward this species is represented by the following variety.

Percina caprodes zebra (Agassiz). Manitou Darter

Said to be the common form in the Great Lakes. "Lake Erie at Sandusky" Osburn ('01). Clemens took it at Merlin, 1920.

Cottogaster copelandi (Jordan). Copeland's Darter

According to Osburn ('01), Henshall of 1889 took this species in Lake Erie at Put-in-Bay. "Great Lakes region, from Lake Champlain to Lake Huron and south" J. & E. Bull. 47 ('96).

Cottogaster shumardi (Girard)

"It occurs also in the Great Lakes and has been reported from Erie and Michigan" Forbes and Richardson ('08).

Diplesion blennioides (Rafinesque). Green-sided Darter

According to Osburn ('01), McCormick of 1892 found this species to be not uncommon in Sandusky bay. Forbes and Richardson ('08) report it "from Lakes Erie and Ontario" and south.

Boleosoma nigrum (Rafinesque). Johnny Darter

"Sandusky bay" Osburn ('01). Typically a darter of the creeks and small brooks.

Ammocrypta pellucida (Baird). Sand Darter

"Taken also in the lake [Erie"] Osburn ('01). Reported by Jordan and Evermann ('96) from Lake Erie to Minnesota, abounding in clear sandy streams.

Etheostoma flabellare Rafinesque. Fan-tailed Darter

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie.

Boleichthys fusiformis (Girard)

"Rather common in shallow water in Sandusky bay" Osburn ('01).

Roccus chrysops (Rafinesque). White Bass

Abundant. A commercial species of minor importance.

Aplodinotus grunniens Rafinesque. Sheepshead

Quite an important commercial species, occurring fairly abundantly and growing to a good size.

Cottus ictalops (Rafinesque). Miller's Thumb

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie. Taken by Crewe at Merlin, 1920.

Lota maculosa (Le Sueur). Burbot; Ling.

Very abundant. In the Great Lakes region it is considered of little value as food. Lake Erie fisherman destroy those taken in the nets because they believe it destructive to other fish. In some places it is esteemed as food.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
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No. 5

RATES OF GROWTH OF THE BLUE AND YELLOW PIKE PERCH

BY

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RATES OF GROWTH OF THE BLUE AND YELLOW PIKE PERCH (*STIZOSTEDION VITREUM*) IN LAKE ERIE

From material obtained during the summer of 1920, at Merlin, Ontario, on Lake Erie, a study has been made, under the direction of Dr. W. A. Clemens, of the rates of growth of the blue and yellow pike perch. These fish, together with the gray pike perch, are described as colour varieties of one species, *Stizostedion vitreum* Mitchell (Jordan and Evermann, 1898, American Fish Manual, 1903). This species is also known as the wall-eyed pike perch, pickerel or doré, the latter being sometimes restricted to the yellow variety.

Apart from their difference in colour, these varieties are also distinguished by their great diversity in size. The blue is apparently the smallest, averaging less than one pound in weight, and occasionally attaining as much as five pounds. The yellow may reach 20 pounds and is often taken weighing from 5 to 10 pounds, and the gray, which is the largest, attains a maximum of 40 pounds, 10 to 20 being common.

The specimens of blue and yellow pike perch obtained at Merlin agree in this divergence in size, but apparently none of the gray variety are caught there by fishermen. Measurements of length, girth, etc., were taken on the specimens of the blue and yellow varieties with a view to the later determination of their respective rates of growth. For this purpose scales from each fish were preserved for the determination of age. The scales were mostly taken from the middle of the sides of the body below the lateral line. In most cases the ear stones were also preserved for use in estimating age.

By microscopic examination of the scales from a fish a fairly accurate estimate of the age can be made. Typical scales of both blue and yellow pike perch are shown in

Figs. 1, 2, 3. From the illustrations it will be seen that the scales are ctenoid; that is, the exposed posterior portion is covered with a number of small spines or teeth. The anterior margin, which is embedded in a pocket of the epidermis and is protected by the overlapping borders of those in front of it, has an entirely different appearance. Instead of being spiny it is fluted and the surface is marked by a large number of fine concentric lines, broken at intervals by radial lines, which pass inward towards the centre from the notches of the scalloped edge. The fine concentric lines are lines of growth, and each represents the addition of a ring

Fig. 1. Scale from a blue pike perch in its fourth summer.

of material to the scale at the border where it is attached to the epidermis.

At regular intervals on the scale the fine lines are laid down alternately closely set and more widely separated. The spacing is wide apart or close together according as the lines were added at a favourable or unfavourable season of the year. This arrangement of lines gives the scale the appearance of having wide light and dark bands when it is examined under the microscope. As shown in Fig. 1 the outer margin is marked by a light band and in the other scales examined a similar area was almost invariably present

in this position. This apparently marks a summer's growth since all the specimens were obtained in summer. The central portion of each scale is surrounded by a dark area which must necessarily represent a late summer's growth and the first winter period, since the fish hatch in spring and the central portion of the scale would be formed during the first summer. This is shown by the illustration of the scale of the smallest blue pike perch in Fig. 2.

By counting the number of dark bands present on a scale the age of the fish can be estimated. Thus, if there are three, as shown in Fig. 1, the fish must have lived three years and some fraction of the fourth summer. However,

Fig. 2. Scale from a blue pike perch in its first summer.

it is impossible to estimate the fraction of a year with any great degree of accuracy. Accordingly, in the present instance, the number of whole years has been determined and an average fraction added to each. Thus, assuming that in general these fish hatch in May, then fish caught in June of the following year would have completed, on the average, a growth period of one year and one month. Similarly, fish caught in July would have completed one year and two months, and fish caught in August, one year and three months. Therefore, the average growth periods of fish caught in June, July and August would be one year and two months. All the fish considered in this study were obtained during the months of June, July and August, and

hence an average of two months has been added to the number of whole years indicated by the scale of any particular fish. Thus the estimated age of the fish whose scale is figured in Fig. 1 is 3 1-6 years and that of the yellow pike perch in Fig. 3 is 2 1-6 years. This arrangement, though quite arbitrary, is justifiable since the measurements of length, weights, etc., must also be averaged in the determination of the rate of growth.

In a great many cases the ear stones of the fish were examined as well as the scales. These also show increase in

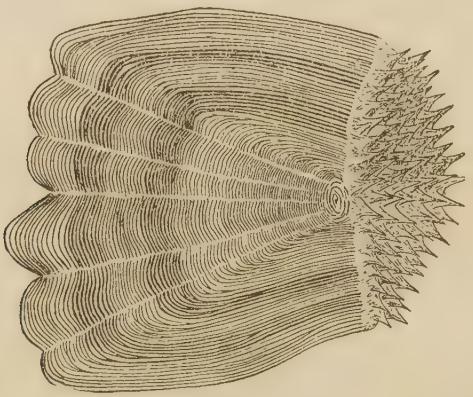

Fig. 3. Scale from a yellow pike perch in its third summer.

size with age and alternate light and dark bands, much like the scales, but they are much more difficult to work with on account of their opacity. However, in a great many cases they could be used to check the results obtained with the scales.

Blue Pike Perch

The data obtained by measurements, and determination of age, of the specimens of the blue pike perch are given in the following table:

No.	Date	Length		Age in yrs.	Weight in oz.	Girth in.
		cm.	inches			
52	Oct. 1920	7.4	2.9	½		
11	July 7	15	5.9	2½	2	3½
10	June 25	17	6.7	2½	3	3¾
1	June 24	17.2	6.8	2½	2½	3⅝
17	July 7	18.1	7.1	2½	2½	
28	July 28	19.2	7.5	3⅙	3	4⅛
48	Aug. 16	19.6	7.7	"	3½	4¾
12	July 7	19.6	7.7	"	3	4⅛
15	July 7	19.7	7.7	"	3	
16	July 7	20.4	8	"	3½	
27	July 28	20.4	8	"	4	5
2	June 24	20.6	8.1	"	4	4⅜
8	June 25	20.7	8.1	"	4	4½
18	July 7	20.7	8.1	"	4	4½
13	July 7	21.0	8.3	"	4	4½
44	Aug. 16	21.0	8.3	"	4	4⅝
38	Aug. 13	21.0	8.3	"	5	4⅝
32	July 30	22.0	8.7	"	4	4¾
30	July 28	22.1	8.7	"	5	5⅛
45	Aug. 16	22.2	8.7	"	5	4⅞
46	Aug. 16	22.3	8.8	"	5	4⅛
37	Aug. 13	22.5	8.8	"	6	5
34	July 30	22.8	9	"	5½	5⅛
19	July 7	22.8	9	"	6	5¼
14	July 7	23.2	9.1	"	6	5¼
39	Aug. 14	23.2	9.1	"	7	5¼
33	July 30	23.8	9.4	"	6½	5⅛
29	July 28	23.8	9.1	"	6	5¼
27	Aug. 16	24.5	9.6	"	7	5¼
43	Aug. 16	24.6	9.6	"	8	5⅝
26	July 28	25.2	9.9	"	8	5⅝
31	July 28	25.5	10	4⅙	8	5⅝
40	Aug. 14	25.5	10	"	9	5⅞
20	July 7	26.7	10.5	"	9	5⅞
49	Aug. 16	27.1	10.7	"	11	6⅛
26	Aug. 13	27.7	10.9	"	12	6½
41	Aug. 14	27.6	10.9	"	11	6¼
25	July 28	28.0	11	5⅙	12	6½
21	July 7	28.0	11	"	12	6½
9	June 25	28.6	11.3	"	17	7½
42	Aug. 16	28.7	11.3	"	10	6⅛
4	June 24	29.0	11.4	"	17	7½
51	Aug. 16	29.6	11.7	"	15	6⅞
50	Aug. 16	29.8	11.7	"	14	6⅞
6	June 25	30.2	11.9	6⅙	17	7¾
5	June 24	30.5	12	"	17	7⅜
22	July 7	30.5	12	"	15	7
3	June 24	31.9	12.5	7⅙	17	7½
7	June 25	31.9	12.5	"	17	7½
23	July 7	33.0	13	"	16	7⅛

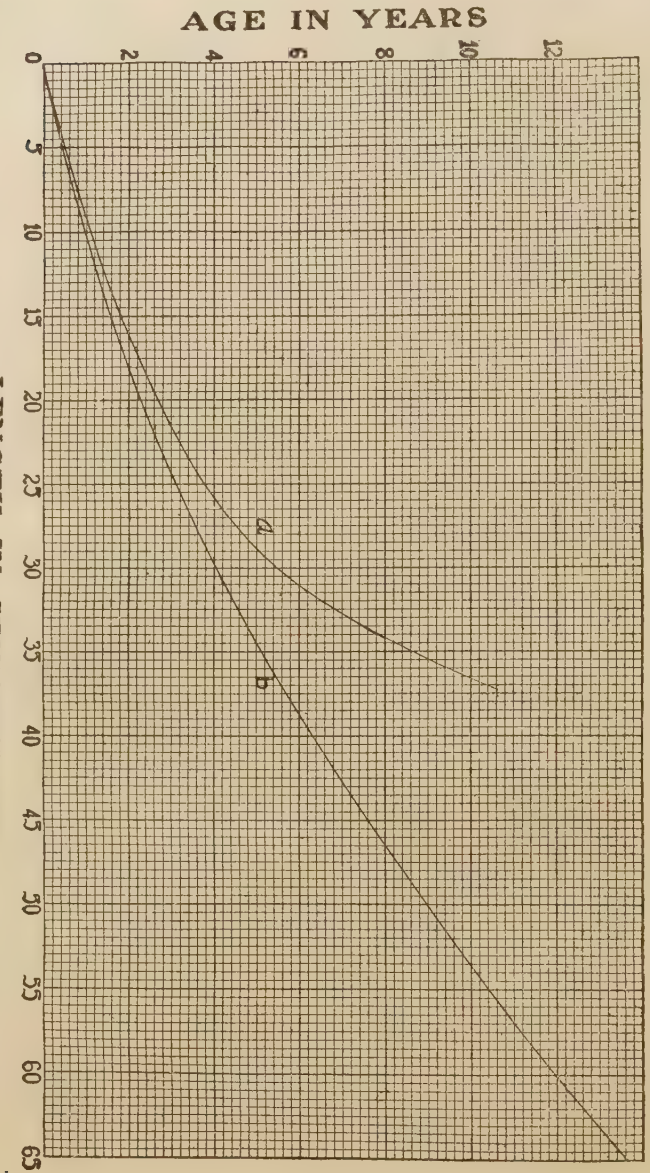

Fig. 4. Graphs showing rates of growth of (*a*) blue pike perch, (*b*) yellowpike perch in Lake Erie.

From the results given above the average length and weight, for each age, have been worked out and are given in the following table:

AGE IN YEARS	LENGTH		WEIGHT IN OZ.
	CENTIMETERS	INCHES	
½	7.4	2.9	
2½	16.8	6.6	2½
3½	21.9	8.6	5
4½	26.4	10.4	10
5½	28.8	11.4	14
6½	30.4	12.0	16⅓
7½	31.9	12.6	16⅔

Using the averages of length and age given in this table, graphs have been drawn (Fig. 4a and 5a) showing the rate of growth of the blue pike perch.

Yellow Pike Perch

A similar determination of the rate of growth of the yellow pike perch has been made from the material collected for the purpose. The results of age determination for these specimens are tabulated below:

No.	Date	Length cm.	Length in.	Age years	Weight oz.	Girth in.
24	Aug. 16	14.7	5.8	2½	2	3⅛
20	July 9	15.1	5.9	"	2	
21	" 9	15.1	5.9	"	2	
13	June 25	15.6	6.2	"	2	
12	" 25	16.3	6.4	"	2	3½
1	" 24	16.8	6.6	"	2½	3½
11	" 25	17.8	7.0	"	3	3⅞
2	" 24	18.2	7.3	"	3	3¾
19	July 9	18.8	7.4	"	3	
18	" 9	18.8	7.4	"	3	
23	Aug. 16	21.0	8.3	"	5	4¾
14	June 25	21.0	8.3	"	4½	4¾
9	" 25	21.0	8.3	"	4½	4½
5	" 24	21.0	8.3	"	4½	4½
3	" 24	21.1	8.3	"	4½	4¾
22	Aug. 16	25.0	9.8	3½	9½	5⅞
4	June 24	28.6	11.2	"	11	6
7	" 24	30.0	11.8	4½	16	6⅞
10	" 25	30.5	12.0	"	14	6½
6	" 24	30.7	12.0	"	14	6½
25	Aug. 18	33.5	13.2	"	1 lb. 6	7⅞
8	June 25	38.7	15.2	6½	2 lb. 3	9½
16	" 30	51.5	20.2	9½	4 lb. 14	12¼
17	July 5	60.5	23.8	12½	8 lb. 14	15½
15	June 30	63.5	25	13½	10 lb. 12	16½

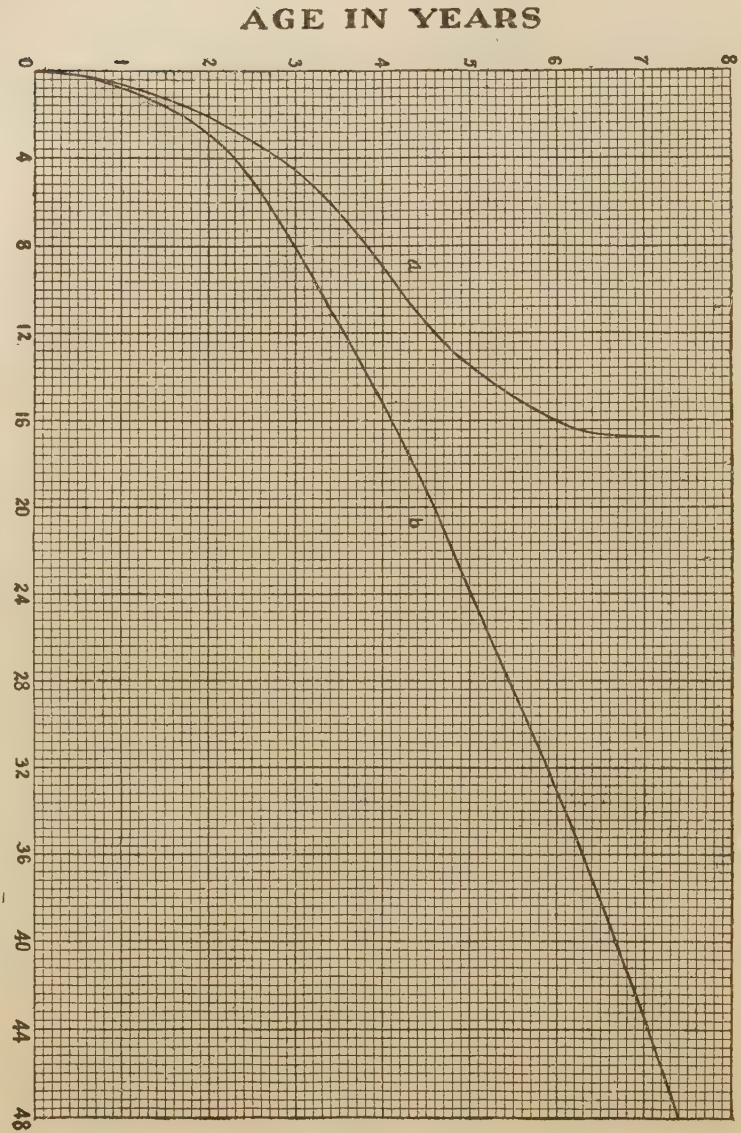

Fig. 5. Graphs showing relation of weight to age, (*a*) blue pike perch, (*b*) yellow pike perch in Lake Erie.

The results given in the preceding table have been used to compute the following table of averages, from which curves illustrating the rate of growth of the yellow pike perch have been drawn in Figs. 4b and 5b.

AGE YEARS	LENGTH CM.	LENGTH INCHES	WEIGHT
2⅙	18.2	7.4	3⅛ oz.
3⅙	26.8	10.6	10¼ "
4⅙	31.2	12.3	16½ "
6⅙	38.7	15.3	2 lb. 3 oz.
9⅙	51.5	20.3	4 " 14 "
12⅙	60.5	24.1	8 " 14 "
13⅙	63.5	25.1	10 " 12 "

A comparison of the two curves obtained brings out the fact that the rate of growth of the yellow pike perch is fairly uniform, whereas, in the case of the blue variety, there is a decided slowing up of the rate of growth at about the end of the fifth year. In both cases, however, there is a falling off in growth with age. In order to show this the lengths at the ages of 1, 2, 3 years, etc., have been obtained by interpolation on the curves, and from these figures the yearly increase in length is obtained.

Age Years	Blue Pike Perch		Yellow Pike Perch	
	Length cm.	Yearly Increment cm.	Length cm.	Yearly Increment cm.
1	9.3		10.3	
2	16.2	6.9	18	7.7
3	21.7	4.5	24.4	6.4
4	25.8	4.1	29.7	5.3
5	28.8	3.0	34.4	4.7
6	31.2	2.4	38.7	4.3
7	32.7	1.5	42.7	4.0
8			46.5	3.8
9			50.2	3.7
10			53.5	3.3
11			56.9	3.4
12			60.2	3.3
13			62.5	2.3

In the case of the blue pike perch the decrease in rate of growth after the fifth year is not compensated by large

increase in weight, as in the case of the yellow variety. Thus, in the fifth summer, the average weight of the blue is 10 oz., which increases to 16 1-3 oz., by the seventh summer, but this increase in weight is accompanied by a very small increase in length.

In the case of the yellow pike perch, on the other hand, the slowing up of growth occurs about the end of the fifth year but the slow growth is more than compensated by the large increase in weight which then begins.

From a consideration of the curves obtained, it would appear that the best time to take the blue pike perch is after the fifth year when they have obtained a length of about 28 to 30 cm. (11 to 12 inches) and weigh 14 to 16 ounces. Since the girth measurement posterior to the gill cover at this age is about 6 inches, this is approximately the size which would be taken in a 3-inch gill net.

With the yellow pike perch, since they increase so rapidly in weight after the sixth year, it would appear that they should not be taken until they have reached a length of at least 15 inches and weigh approximately 2 lbs.

The study of the rates of growth of the blue and yellow pike perch shows that the former do not reach nearly so great a size as the latter, and amply confirms the opinion of fishermen that the blue are much smaller. Moreover, after the fourth year the rate of growth of the blue variety falls off very rapidly, whereas the yellow continue to grow uniformly up to a considerable age. This peculiar difference in the rates of growth possibly indicates some basic physiological distinction between the two varieties which also possibly finds expression in their difference in colour.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 6

THE RATE OF GROWTH OF THE YELLOW PERCH (*PERCA FLAVESCENS*) IN LAKE ERIE

BY

W. J. K. HARKNESS

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1922

THE RATE OF GROWTH OF THE YELLOW PERCH (*PERCA FLAVESCENS*) IN LAKE ERIE

As shown in the returns given in the annual reports of the Department of Game and Fisheries of the Province of Ontario, the catch of yellow perch (*Perca flavescens* Mitchell) in Canadian waters of Lake Erie has practically doubled in the past ten years. In 1919 the catch amounted to 1,096,935 pounds, valued at $87,755. In view of this increasing value of the yellow perch fishing industry in Lake Erie, it seemed desirable to obtain some definite information as to the rate of growth of this fish.

The study was undertaken at the suggestion of Professor W. A. Clemens, and carried out under his direction. The material was obtained by Dr. Clemens, at the Crewe Bros. Fishery, Merlin, Ontario, during the summer and autumn of the year 1920.

The age of the fish was determined by counting the seasonal growth areas on the scales. The scales found most satisfactory were those from the region about the middle of the body below the lateral line. An examination of a perch scale shows alternating light and dark areas. It has been taken for granted that the light area corresponds to a period of rapid growth which would take place during the summer months, while the darker area, where the lines are more crowded, represents a period of slower growth which no doubt occurs during the winter months. This interpretation of the areas on the scale is supported by the fact that the scales from perch taken in late summer show a distinct light area on the margin, while those from perch taken in early summer show a dark area on the margin. Figure 1 illustrates the characteristics of a perch scale, and the method used in age estimation. Table 1 shows the results of this study coördinated.

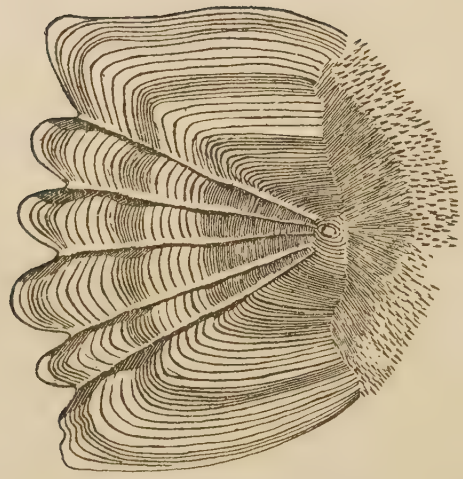

Fig. 1. Scale of a yellow perch at the beginning of its fourth summer.

TABLE 1. DATA ON RATE OF GROWTH OF YELLOW PERCH IN LAKE ERIE.

Age	Number of Fish Examined		Length in cm. to base of caudal fin			Length in inches over all	Girth in inches just posterior to the gills	Weight in Ounces	
	Actual Number	Percentage of Total No.	Average by Measurement	Average by Estimating	Estimated Increase from Year to Year			Average by Observation	Estimated Increase from Year to Year
½ year	1	1.3	4.4	5.0		2			
					5.0				
1½ "	0	0		10.0					
					4.0				
2½ "	30	40.5	14.4	14.0		6.6	4.4	2.6	
					3.0				1.7
3½ "	18	24.0	16.8	17.0		7.7	5.1	4.3	
					2.5				1.4
4½ "	13	18.0	18.7	19.5		8.5	5.7	5.7	
					2.0				3.5
5½ '	4	5.2	21.7	21.5		9.9	6.6	9.2	
					2.0				2.4
6½ "	4	5.2	23.4	23.5		10.8	7.3	11.6	
					1.0				1.2
7½ "	4	5.2	24.4	24.5		11.0	7.2	12.8	

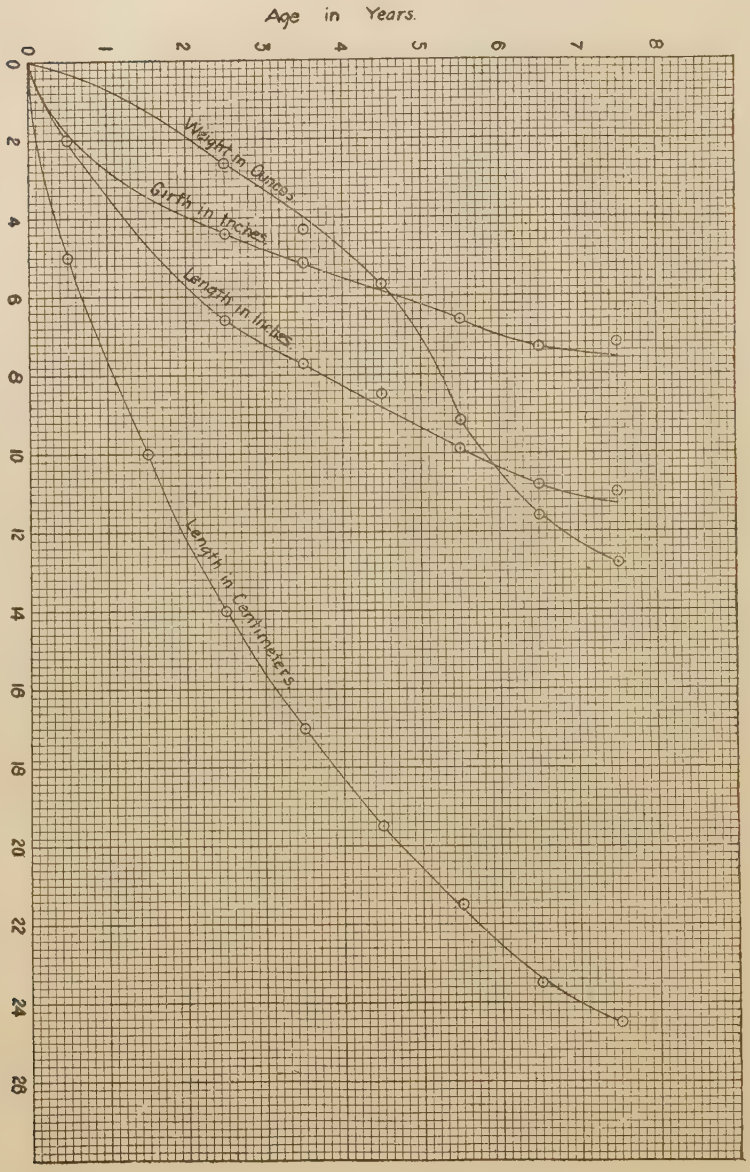

Fig. 2. Graphs showing rate of growth of yellow perch in Lake Erie.

Fig. 2 is a graph showing the relation of age to length in centimeters, length in inches, girth in inches and weight in ounces.

Embody (1915) gives the following table for the growth of yellow perch as compiled from data obtained on the fish growing in natural waters in the vicinity of Ithaca, N.Y.

Age	Length in in. over all	Length in cm. over all	Length in cm. to base of caudal fin
5 months	2–2.5	5–6.5	3.5–5
1 year	3–4	7.5–10	5.5–8
2 years	6–7	15–17.5	13–15.5
Spawn	April		
Advanced fry	May–June		
Fingerlings	September		

The measurements given by Embody have been reduced to centimeters, and the last column shows the approximate lengths of these fish to the base of the caudal fin. These figures agree very closely with the data compiled from fish growing in Lake Erie as do also those of Pearse and Achtenberg (1920) who give the lengths of yellow perch taken in Lake Mendota, Wis., in the first summer as 2.9 cm. on July 7 to 6.1 cm. on August 24.

If the fish are taken before they reach maturity and are thus prevented from spawning, the supply of that species will soon become depleted. This is amply exemplified by the disappearance of the trout from many of the Ontario streams, and the bass from the lakes.

It is believed that the fish studied are a fair average of the total catch. By a study of table 1 and Fig. 2 it is seen that approximately

40 per cent. of all the perch caught were 2½ years old averaging 14.0 cm. (6.6 in.) in length, 4.4 inches in girth and 2.6 ounces in weight.

24 per cent. of all the perch caught were 3½ years old averaging 17.0 cm. (7.7 in.) in length, 5.1 inches in girth and 4.3 ounces in weight, an increase of 1.7 ounces over the 2½ year old perch.

18 per cent. of all the perch caught were 4½ years old averaging 19.5 cm. (8.5 in.) in length, 5.7 inches in girth and 5.7 ounces in weight, an increase of 3.1 ounces over the 2½ year perch, and only

5.2 per cent. of all the perch caught were 5½ years old averaging 21.5 cm. (9.9 in.) in length, 6.6 inches in girth and 9.2 ounces in weight, an increase of 6.6 ounces over the 2½ year old perch.

Pearse and Achtenberg (1920), judging by the measurements made on individuals from a school of young perch which remained near the base of Picnic Point, Lake Mendota, during the summer of 1916, and by observations of the gonads of half grown perch at various seasons, believe that perch may become sexually mature in Lake Mendota at the end of two years of growth. No information was obtained as to the age when the yellow perch first spawns in Lake Erie waters, but it probably is the end of the third year.

Yellow perch increase most rapidly in weight between the age of 3½ and 5½ years (Fig. 2). During these two years the perch in Lake Erie increase on an average about 5 ounces, which is more than their weight at 3½ years of age (Fig. 2).

It would appear from the data at hand, that no yellow perch should be caught which are less than 4½ years old. In other words from the standpoints of conservation and of monetary returns this fish should be taken when about 8 to 10 inches in length. This would allow the fish to spawn at least twice, and this would tend to ensure an inexhaustible supply. This would also give the fisherman a larger supply of a much more satisfactorily marketable fish. Unless some protection is given there is danger of the yellow perch fishery in Lake Erie becoming depleted in a few years if the rate of increase in the amount of catch during past few years is maintained.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 7

THE RATE OF GROWTH OF THE WHITE FISH (*COREGONUS ALBUS*) IN LAKE ERIE

BY

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1922

THE RATE OF GROWTH OF THE WHITE FISH (*COREGONUS ALBUS*) IN LAKE ERIE

The purpose of this investigation has been to obtain some definite information concerning the rate of growth of whitefish in Lake Erie. The study was undertaken at the suggestion of Dr. W. A. Clemens to whom the writer desires to express his appreciation of the kind assistance given.

The specimens were procured from points along the north shore of Lake Erie (Kingsville, Merlin, Ridgetown and Nanticoke) through the kindness of Messrs. B. Wescott, A. E. Crewe, W. D. Bates and A. B. Hoover. For purposes of comparison eight specimens of whitefish were obtained from Port Credit on Lake Ontario and two from Hudson Bay. The latter were collected by Rev. W. G. Walton on July 22, 1919, at Great Whale river.

Identification

The fish from Lake Erie are here referred to the species *C. albus* Le Sueur, while those from Lake Ontario to *C. clupeaformis* (Mitchell) following Jordan and Evermann (1911). By way of comparison detailed measurements were taken of three specimens from Lake Erie, numbers 101, 102 and 105; three from Lake Ontario, numbers 66, 67 and 68; and the two from Hudson Bay, numbers 131 and 132. All the specimens had been preserved in formalin and alcohol some time previous to the time the measurements were made. The results are shown in the following table:

	LAKE ERIE				LAKE ONTARIO				HUDSON BAY		
SpecimenNo.	102	103	105	Av.	66	67	68	Av.	131	132	Av.
Body length (mm.)	558	428	382		462	350	418		302	234	
Dorsal rays	13	11	12		13	11	11		14	13	
Anal rays	13	14	13		11	12	13		13	13	
Scales	85	81	85		84	87	84		78	79	
Gill rakers	22	25	28		25	26	25		26	25	
*Head	.20	.21	.19	.20	.21	.22	.21	.21	.235	.22	.23
Body depth	.29	.34	.29	.31	.28	.24	.23	.25	.275	.27	.27
C.P. length	.07	.09	.08	.08	.11	.09	.10	.10	.11	.11	.11
C.P. depth	.09	.10	.08	.09	.08	.08	.07	.08	.09	.09	.09
Eye	.03	.04	.03	.03	.035	.04	.04	.04	.05	.05	.05
Maxilla	.05	.05	.05	.05	.05	.05	.055	.05	.07	.07	.07
Pectoral length	.16	.17	.16	.16	.18	.17	.17	.17	.19	.17	.18
Pelvic length	.15	.15	.14	.15	.17	.16	.165	.165	.17	.18	.175
Dorsal height	.16	.17	.17	.17	.18	.18	.18	.18	.19	.21	.20
Anal length	.13	.13	.105	.12	.13	.14	.13	.13	.13	.11	.12

*Measurements given as decimal fractions of body length.

The results for the Lake Erie and Lake Ontario fish agree closely with those given by Jordan and Evermann (*loc. cit.*) and Bensley (1915). For the Hudson Bay fish several slight though interesting variations appear. The caudal peduncle appears to be longer; the diameter of the eye greater; the length of the maxilla greater; the height of the dorsal greater; the lengths of the pectoral and pelvic fins greater, and the scales on the lateral line fewer. In spite of these differences there is a close resemblance to the Lake Ontario whitefish and it seems advisable for the present to refer these two fish to the species *C. clupeaformis.*

Rates of Growth

The rate of growth was determined by plotting curves between the age ascertained from the scales and the length and weight determined by direct measurement. The scales for determining the age were taken from the side of the fish, some from just below the anterior part of the dorsal fin, some near and including the lateral line, and some from just before the pelvic fin where the scales are large. The round even scales from the dorso-lateral region were found to be more satisfactory than those from the ventro-lateral region. The latter were larger but had radiate markings and ridges on them and the summer and winter areas were not so well defined. The vertebrae and otoliths of some specimens were preserved as a secondary means of determining the age but they were found to be much less reliable beyond three years of age. The method of determining the age from the scales is illustrated in figure 1. It is assumed that the areas with widely separated lines represent spring and summer periods when growth conditions are at their best. Conversely the closely spaced areas represent the winter months. In Fig. 1 the upper two scales (A and B) are from whitefish from Lake Erie aged two and five years respectively. The lower two (C and D) are from the whitefish from Hudson Bay, aged five and ten years respectively. All scales are enlarged to the same degree, i.e. fifteen diameters. The scales and likewise the fish themselves from Hudson Bay

are smaller than those from Lake Erie, although the former are much older. This apparently furnishes a striking illustration of the effect of cold water on the growth of these fish.

The rates of growth of the fish examined are shown in Fig. 2. The results indicate that during the first two or

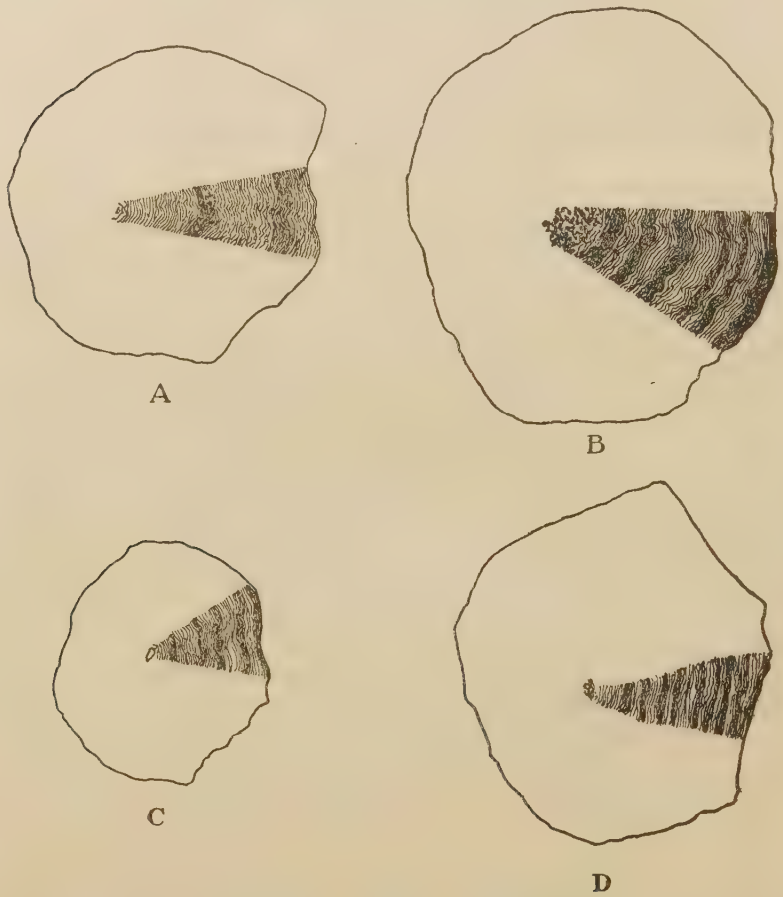

Fig. 1. Scales from whitefish from Lake Erie and Hudson Bay.
A and B from Lake Erie, third and sixth summers respectively.
C and D from Hudson Bay, sixth and eleventh summers respectively.

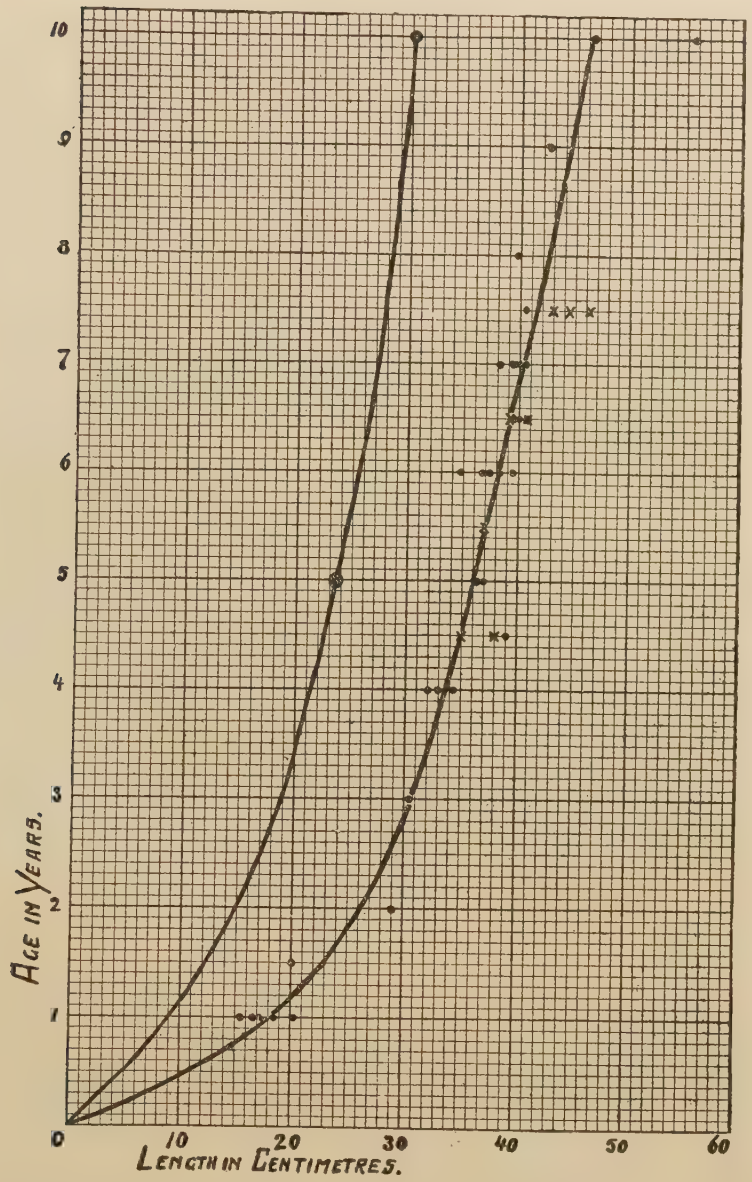

Fig. 2. Graphs illustrating rates of growth of whitefish from Lake Erie and Hudson Bay.

O, whitefish from Hudson Bay.
o, " " Lake Erie.
X, " " Lake Ontario.

three years the fish grow quite rapidly in length, then gradually the rate of growth lessens and the increase in length with age is much less noticeable. They do however, continue to increase in length until ten or twelve years of age and probably throughout their entire lives. The eight specimens from Lake Ontario are also shown on the graph although the number is too small to warrant a curve. However, they appear to have a rate of growth somewhat similar to that

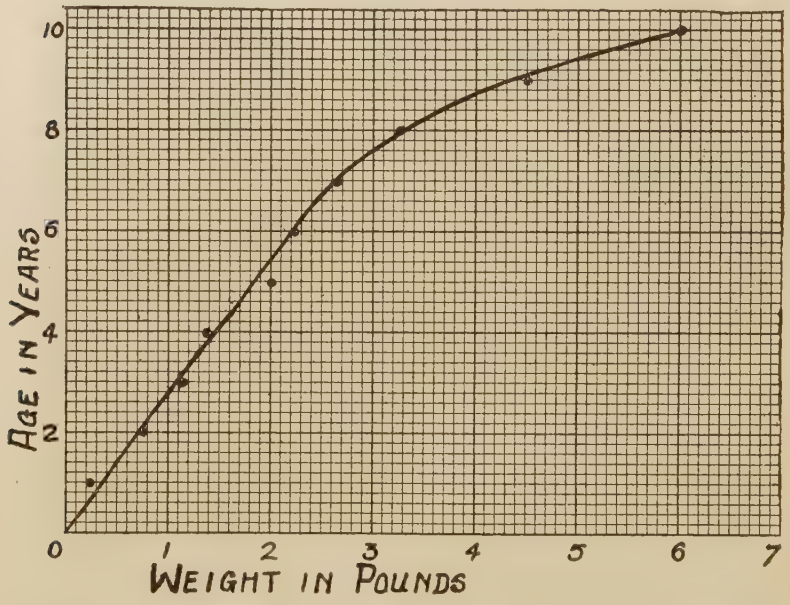

Fig. 3. Graph showing rate of increase in weight with age, whitefish, Lake Erie.

of the Lake Erie fish. The two from Husdon Bay are also shown and an approximate curve projected through them. Here also it is strikingly demonstrated that the rate of growth in cold water is much slower than in such waters as Lake Erie. Since a fish is a "cold-blooded" animal its body temperature in cold water is low, and it follows directly that its metabolic reactions are all depressed and hence that growth is retarded.

The fish were weighed at the same time that the scales were removed and the lengths determined. It is interesting to compare the rate of increase of length with age (Fig. 2) and the rate of increase of weight with age (Fig. 3).

Since the conditions of the fish, such as the amount of fat and the development of the gonads, result in considerable differences in weight, the average of all the fish in each year was taken and this is used in this curve. It indicates that

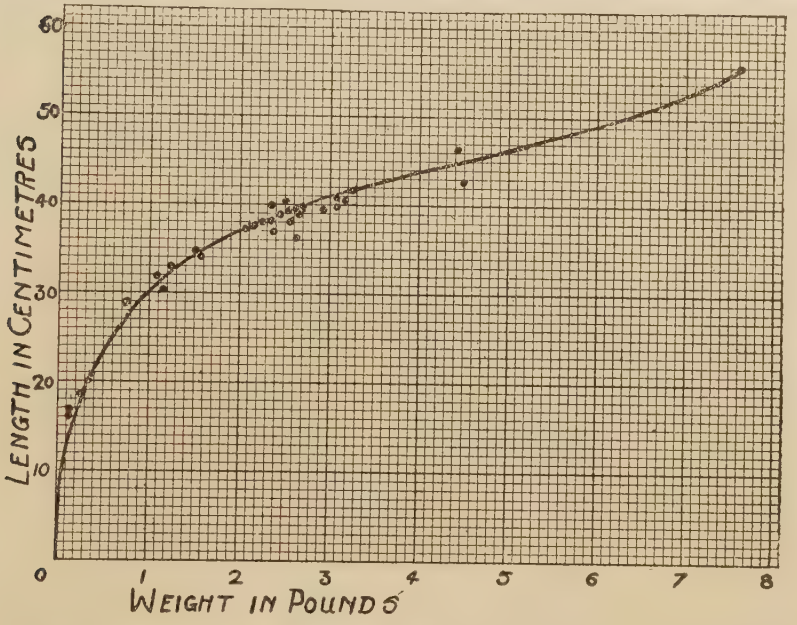

Fig. 4. Graph showing relation between length and weight, whitefish, Lake Erie.

the fish increase quite uniformly in weight up to four or six years of age, after which they increase rapidly relative to age and also to length. This is of the utmost importance from a commercial standpoint as the weight obviously bears a direct relation to food value. If left to the age of seven to ten years (40-50 cm.) the fish would have passed through that period when there is the greatest relative increase in weight. The wisdom of such a course is obvious. Another

phase of this matter has been illustrated in Fig. 4 where weight and length have been plotted. In this graph each individual fish was recorded. It shows that at first the fish develops rapidly in length for a small increase in weight. Then at about 35 cms. the rate of growth in length decreases and the fish begins to increase in weight. This rapid increase in weight and comparatively slow increase in length continues at least up to ten years of age though probably soon after this age the rate of increase in weight falls off again. The curve corroborates the deductions drawn from Figs. 2 and 3.

DATA—*COREGONUS ALBUS*—LAKE ERIE

Specimen No.	Date	Length cm.	Girth cm.	Weight lb. oz.	Age Years	Sex
1	May 1919	32.0		1 lb. 1 oz.	4	
2	"	29.0		0 " 12 "	2	
3	"	20.0		0 " 5 "	1½	
25	June 6	37.0		2 " 6 "	5	♀ very fat
26	"	46.5		4 " 7 "	10+	♀ fat
27	"	33.0		1 " 4 "	4	♀
28	"	34.3		1 " 9 "	4	♂ fat
29	"	30.3		1 " 2 "	3	♂
30	"	34.8		1 " 8 "	6	♂
31	"	18.5	10.1		1	
32	"	17.1	9.5		1	
33	"	15.7	8.8		1	
34	"	15.6	8.8		1	
50	June 25/20	16.8	10.1	0 " 2 "	1	
51	"	18.5	12.6	0 " 4 "	1	
52	July 5	20.3	14.5	0 " 5 "	1	
53	" 6	16.1	11.0	0 " 2 "	1	
54	" 13	36.5	39.8	2 " 10 "	5	
100	Dec. 6	39.6		2 " 15 "	6½	♀ large eggs
101	"	42.8		4 " 8 "	9	♀ " "
102	"	55.8		7 " 10 "	10	♀ spent
103	"	40 0		3 " 2 "	6½	♀ large eggs
104	"	40.5		2 " 8 "	7	♀ spent
105	"	38.2		2 " 5 "	6	♀ large eggs
106	"	39.3		2 " 7 "	7	♂ large testes
107	"	40.6		3 " 2 "	7	♂ partly spent
108	"	39.6		2 " 9 "	6	♂ " "
109	"	37.3		2 " 1 "	6	♂ " "
110	"	40.5		3 " 3 "	7½	♀ large eggs
111	"	38.1		2 " 9 "	7	♂ fat
112	"	39.9		2 " 11 "	8	♂ partly spent
113	"	41.8		3 " 4 "	6½	♀ large eggs
114	"	37.8		2 " 2 "	6	♀ partly spent
115	"	39.0		2 " 10 "	4½	♀ " "
116	"	39.7		2 " 10 "	7	♀ entirely "
117	"	40.3		2 " 8 "	7	♀ " "
118	"	38.1		2 " 4 "	6	♂ partly spent
119	"	39.4		2 " 11 "	6	♀ large eggs
120	"	40.0		2 " 5 "	7	♀ spent

DATA—*COREGONUS CLUPEAFORMIS*—LAKE ONTARIO

No.	Date	Length cm.	Weight	Age Years
61	Dec. 2, 1920	44.5	2¾ lb.	7½
62	"	38.0	1¾ "	4½
63	"	39.3	2¼ "	6½
64	"	37.0	1⅝ "	5½
65	"	43.0	2¾ "	7½
66	"	46.2	3 lb. 13 oz.	7½
67	"	35.0	1 " 6 "	4½
68	"	41.8	2 " 7 "	6½

DATA—*COREGONUS CLUPEAFORMIS*—HUDSON BAY

No.	Date	Length cm.	Age Years	
131	July 22 1919	30.2	10	Great Whale River
132	"	23.4	5	" " "

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Bensley, B. A., 1915. The Fishes of Georgian Bay. Contrib. Canad. Biol. 1911-14, Fasc. II, Fresh Water Fish and Lake Biology. Biological Board of Canada, Suppl. 47th Ann. Rep., Dept. Marine and Fisheries, Fisheries Branch, Ottawa, p. 30-32.

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 8

REPRESENTATIVE *CLADOCERA* OF SOUTH-WESTERN ONTARIO

BY

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REPRESENTATIVE *CLADOCERA* OF SOUTH-WESTERN ONTARIO

During the past two years the author of this paper has made a special study of the *Cladocera* in various parts of the Province of Ontario. In view of their common occurrence in practically all bodies of water and their fundamental economic importance, it is surprising that but little attention has heretofore been given to this interesting group in our province. Sars (1916) lists nine species found in samples of surface plankton collected during the summer of 1907 in the Go Home Bay region of Georgian Bay and submitted to him for examination by Professor E. M. Walker. The *Cladocera* of that list are as follows:—

Holopedium gibberum Zaddack

Sida crystallina (Müll.)

Daphniella brachyura Liéven = (*Diaphanasoma brachyurum*)

Daphnia hyalina var. *oxycephala* Sars = (*Daphnia longispina* var. *hyalina*)

Hyalodaphnia retrocurva var. *intexta* Forbes (*Hyalodaphnia* = *Daphnia*)

Ceriodaphnia scitula Forbes (probably = *C. quadrangula* Müll.)

Bosmina longirostris (Müll.)

Polyphemus pediculus (L.)

Leptodora hyalina Lilljeb. = (*L. kindtii* Focke)

Birge (1918) mentions *Chydorus latus* Sars as "rare, Canada, near Lake Erie". Birge (1894) lists a number of *Cladocera* taken in the American waters of Lake St. Clair, Detroit River and the western end of Lake Erie. No doubt

these species also occur in the Canadian waters of these regions.*

In the present paper the occurrence of forty-nine species of *Cladocera* is recorded. The classification and arrangement of these is based on Birge (1918). The material studied came from the following localities, which are indicated on the accompanying map (Fig. 1).

1. Georgian Bay. Several hundred samples of plankton collected during the years 1903, 1905 and 1907 from eight stations in the Go Home Bay region in the south-eastern part of Georgian Bay under the direction of Professor B. A. Bensley and Professor E. M. Walker were kindly placed at the writer's disposal for examination. Also the stomach contents of 19 ciscoes (*Leucichthys harengus*) taken in the south-western part of Georgian Bay have been examined. These were obtained in November 1920 from Wiarton by Professor W. A. Clemens. In the locality records in the following part of the paper, Georgian Bay, unless otherwise stated, refers to the Go Home Bay region.

2. Port Sydney. This small village is situated on Lake Mary about 15 miles from the town of Huntsville in the Muskoka District. In the summer of 1919 plankton collections were made in various small lakes, ponds and pools within a radius of four miles of this village and also in the north branch of the Muskoka River.

3. Toronto. Plankton collections were made in Grenadier Pond, in the lagoons on Toronto Island and in various small ponds and pools in the immediate vicinity of this city. These collections were made mostly in the spring and autumn of 1919 and the spring of 1920.

4. Lake Ontario. The stomach contents of seven ciscoes (*L. ontariensis*) obtained by Professor W. A. Clemens at Port Credit in November, 1920, have been examined.

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*Since the above was written an article has appeared entitled "Notes on Canadian Entomostraca," by A. Brooker Klugh, in the Canadian Field Naturalist, vol. XXXV, No. 4, pp. 72-73, 1921. In this paper twelve species of *Cladocera* are recorded from four localities in Ontario, all of which localities are other than those mentioned in the present paper.

5. Bond Lake and Wilcox Lake. These two small lakes are situated about 20 miles north of Toronto. During the spring and autumn of 1919 and the spring of 1920 plankton hauls were made in these lakes as well as in several small ponds and pools in their immediate vicinity.

6. Lake Erie. The alimentary tracts of approximately 200 ciscoes from Lake Erie have been examined. Four species were represented, namely *L. eriensis*, *L. artedi*, *L. sisco huronius* and *L. prognathus*, and were obtained by Professor W. A. Clemens from various points along the north shore of Lake Erie in the spring of 1919 and the summer and autumn of 1920. Since ciscoes are pre-eminently plankton feeders, much interesting information concerning the distribution of *Cladocera* was gained from this source.

7. Point Pelee. Samples of plankton were taken during the summer of 1920 from various types of permanent and temporary ponds and pools on this point of land, the southernmost point of Canadian soil.

The drawings with which this paper is illustrated were all made from specimens collected in the various localities mentioned above.

SIDIDAE

Sida crystallina (Müller)

Georgian Bay, Lake Erie, Point Pelee. This species appears to seek the shallower water close to shore especially in the vicinity of aquatic plants and was not found in small ponds or pools unless they were immediately adjacent to larger bodies of water. It is a rather important form from the standpoint of fish food since it ranked third in the list of organisms most commonly found in cisco stomachs, *Daphnia* and *Leptodora* respectively exceeding it in frequency. Forty-eight jumbo ciscoes taken from June 1 to August 2, 1920, at Merlin chiefly, but also at Rondeau, Lake Erie, had eaten it in considerable numbers.

Latonopsis occidentalis Birge

Point Pelee. Fairly common June 18, 1920, in a small weedy pond near Lake Pond.

Latona setifera (Müller)

Georgian Bay, Point Pelee (Lake Pond). Apparently uncommon in Georgian Bay since only a single specimen was taken. Five specimens were found in July and August in plankton swept from aquatic vegetation in Lake Pond (Point Pelee).

Diaphanosoma brachyurum (Liéven)

Georgian Bay, Lake Erie, Point Pelee. In some samples of plankton this species was fairly common and a few specimens were observed in two cisco stomachs (*L. eriensis*) from Merlin in July and August 1920.

Diaphanosoma leuchtenbergianum Fischer

Georgian Bay, Point Pelee. Less common than the preceding species.

HOLOPEDIDAE

Holopedium gibberum Zaddach

Georgian Bay, Lake Erie. This species occurred very abundantly in most of the open water plankton from Go Home Bay and a few were taken from a cisco stomach (*L. eriensis*) from Lake Erie, July 1920.

DAPHNIDAE

Of the members of this family the genus *Daphnia* is the most widely distributed and the most abundant in point of individuals. Their immense numbers, their great economic importance as fish food and their amazing variations among individuals of the same species can only be fully appreciated by those who have made a study of fresh water plankton and the contents of fish stomachs. In a great many ciscoes

examined the entire alimentary tracts were found to be literally crammed with the remains of countless thousands of *Daphnia*. Of 205 of these fish examined 160 had eaten *Daphnia* to a greater or less extent. In the majority, *Daphnia* were by far the most abundant food organisms present and in 26 formed the entire food material. The only ciscoes which had not fed largely on *Daphnia* were some taken in the spring of 1919 when *Ephemeridae* formed the bulk of the food material, and a few others taken in the deep open waters where *Mysis relicta* and *Limnocalanus macrurus* were the dominant crustaceans.

Daphnia pulex (de Geer)

Port Sydney, Toronto, Lake Ontario, Bond Lake, Lake Erie, Point Pelee. Generally common everywhere in bodies of water of all sizes from large lakes to small temporary pools. However it was not found in the Georgian Bay plankton which is surprising in view of the large numbers of samples taken. Neither was it found in any of the cisco stomachs from the eastern portion of Lake Erie. It appears to be the commonest species in the western part of this lake, however, and apparently forms the bulk of the food of the ciscoes there during summer and autumn at least. The majority of the jumbo ciscoes (*L. eriensis*) taken during the summer and autumn of 1920 had eaten this species together with some *Daphnia retrocurva* which may be only a form of *D. pulex*, and all the individuals of this species taken during November 1920 had eaten *D. pulex* only.

Daphnia retrocurva Forbes

Georgian Bay, Lake Ontario, Lake Erie. Abundant in the plankton from Georgian Bay and very abundant in the cisco stomachs from Lake Erie. It appears to be a summer form in Lake Erie as ciscoes taken at Rondeau in June 1919 had eaten almost as many individuals of this species as of *D. pulex*. Many of these specimens showed astonishing variations in the shape and extent of the cephalic crest as shown in Figs. 1-4. One individual with a pronounced

retrocurva crest had the same type of pecten on the claws of the post abdomen as is found in typical *D. pulex*. Forms approaching the *D. arcuata* type were also found. In spite of the amazing differences between typical specimens of *D. retrocurva* and *D. pulex* the indications point strongly to the conclusion that the two forms may be extreme variations of one species. It is not improbable that a careful study of these forms at Rondeau during the month of June might establish their identity.

Daphnia longispina (Müller)

Georgian Bay, Toronto, Lake Ontario, Bond Lake, Lake Erie. Very abundant, ranking next to *D. pulex* in numbers. It is an exceedingly polymorphic species. In the smaller lakes and larger ponds var. *hyalina* form *typica* was the most common phase. Form *typica* was found in Bond Lake and Grenadier Pond (Toronto), but in the latter body of water two remarkable variations occurred in May 14, 1920, as shown in Figs. 5 and 6. One had a protuberance over the region of the heart as is found in *D. pulex* var. *minnehaha*, while the other had a minute downward projecting crest on the head. In any large collection of *Daphnia longispina* it has been found that variations in form are not uncommon.

In the larger lakes form *galeata* seems to be the prevailing form of this species. In his list of the *Entomostraca* of Georgian Bay, Sars mentions the *Daphnia* from Go Home Bay region as *D. hyalina* var. *oxycephala* although at first inclined to consider it as *D. galeata*. The results of the present studies would indicate that the form he was dealing with was *D. longispina* var. *hyalina* form *galeata* according to the generally accepted nomenclature of the present time. It is much the commonest species in the southern part of Georgian Bay in the plankton and cisco stomachs examined. It occurred in nearly all of the plankton samples in varying numbers and abundantly in all of the stomachs of the nineteen Georgian Bay ciscoes (*L. harengus*) examined, along with *Diaptomus* and *Epischura*. Five out of seven Lake Ontario ciscoes (*L. ontariensis*) taken at Port

Credit in November 1920 had eaten this species almost entirely. In Lake Erie form *galeata* of *D. longispina* is the prevailing form but is much less abundant than either *D. pulex* or *D. retrocurva*. Jumbo ciscoes from Merlin, Ontario, taken during July and early August 1920 had eaten this species almost entirely.

In Figs. 7, 8 and 9 are shown some extreme variations such as are occasionally found scattered among ordinary specimens of this species.

Simocephalus vetulus (Müller)

Toronto (Grenadier Pond), Bond Lake, Point Pelee. Fairly common in the above mentioned localities among aquatic vegetation and doubtless widely distributed.

Scapholeberis mucronata (Müller)

Toronto, Lake Wilcox, Port Sydney. Commonest in small pools in these localities but also found in shallow water along the margins of lakes.

Scapholeberis aurita (Fischer)

Point Pelee. Found only about the middle of July 1920 in a small muddy pool in a pasture where it occurred sparingly in a plankton composed mostly of *Ceriodaphnia reticulata* and *Moina affinis* (Fig. 10).

Ceriodaphnia reticulata (Jurine)

Toronto, Bond Lake, Point Pelee. Only found in small pools or ponds but very abundant when found (Fig. 11).

Ceriodaphnia lacustris Birge

Georgian Bay, Toronto (Lagoon on Toronto Island). Not common.

Ceriodaphnia quadrangula (Müller)

Georgian Bay, Point Pelee (Lake Pond). This is probably the *Ceriodaphnia scitula* mentioned by Sars in his list of *Entomostraca* from Georgian Bay.

Ceriodaphnia pulchella Sars

Point Pelee. Taken during the months of July and August 1920 in some rather large ponds.

Moina affinis Birge

Point Pelee. This cladoceran was very common during the month of July 1920 in a small muddy pool in a pasture, along with *Ceriodaphnia reticulata* and a few *Scapholeberis aurita*. Most of the specimens were covered with a minute unicellular organism, a few of which are shown attached to the post abdomen in Fig. 12. This species also occurred in a few temporary rain pools along a roadway.

BOSMINIDAE

Bosmina longirostris (Müller)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Wilcox Lake, Lake Erie, Point Pelee. This is one of the most widely distributed of all our *Cladocera*. Some specimens from Go Home Bay appear to have the spine on the posterior ventral extremity of the valves longer than is usual in this species. This fact was noted also by Professor G. O. Sars in his examination of Go Home plankton collected in 1907.

Bosmina longispina Leydig

Port Sydney. The only specimens identified with certainty as belonging to this species were two taken June 18, 1919, from the north branch of the Muskoka River. Eventually this species may prove to be but an extreme variation of the preceding one as some specimens of *Bosmina* from Go Home Bay have been found to be intermediate in many respects between the two.

MACROTHRICIDAE

Macrothrix rosea (Jurine)

Point Pelee (Lake Pond). A few specimens were taken in plankton swept from among weeds, August 22, 1920.

Illiocryptus spinifer Herrrick

Toronto. Two brilliant red specimens of this species were found in December, 1918, creeping about among a thick growth of *Chara* in a small stream near Grenadier Pond, Toronto.

Illiocryptus sordidus (Liéven)

Point Pelee (Lake Pond). Common in August, 1920, in plankton swept from aquatic vegetation. The post abdomen of one of these specimens is shown in Fig. 13. Some individuals were very light yellow in colour and others were quite transparent.

Acantholeberis curvirostris (Müller)

Georgian Bay, Port Sydney. Occurred sparingly in plankton collected from the shallower parts of Go Home Bay, but very abundantly in a small pond in the middle of a sphagnum bog situated about four miles south of Port Sydney.

Drepanothrix dentata (Eurén)

Georgian Bay. Apparently rare since it occurred in only a few of the many samples (Figs. 15-16).

Streblocerus serricaudatus (Fischer)

Bond Lake. Only one small specimen taken in plankton, November 9, 1919.

Ophryoxus gracilis Sars

Georgian Bay. Not uncommon in plankton collected from shallow waters (Fig. 14).

CHYDORIDAE

Eurycercus lamellatus (Müller)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Lake Erie, Point Pelee. Common in the weedy parts of ponds and lakes.

Camptocercus rectirostris Schoedler

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Very common, November, 1919, in Bond Lake.

Kurzia latissima (Kurz)

Georgian Bay, Toronto (Grenadier Pond), Point Pelee. Only a few specimens were taken in each of these localities.

Acroperus harpae Baird

Bond Lake, Point Pelee. Especially common in November, 1919, in Bond Lake.

Acroperus angustatus Sars

Bond Lake. Apparently this species is only a form of the preceding species since many forms intermediate between the two were taken on November 9 and 15, 1919, in Bond Lake.

Leydigea quadrangularis (Leydig)

Georgian Bay, Toronto (Grenadier Pond), Point Pelee. Only one or two specimens were found in each of these localities (Fig. 17).

Alona guttata Sars

Toronto (Grenadier Pond and also in smaller ponds and pools), Bond Lake, Point Pelee. Very abundant.

Alona affinis (Leydig)

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Occurred most abundantly in the plankton from the shallow weedy parts of Go Home Bay.

Graptoleberis testudinaria (Fischer)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Point Pelee. Only a few specimens were found in each of these places.

Pleuroxus denticulatus Birge

Port Sydney, Toronto, Bond Lake, Point Pelee. Never found in open water plankton.

Pleuroxus trigonellus (Müller)

Port Sydney, Toronto (Grenadier Pond), Bond Lake, Point Pelee (Lake Pond). Several specimens were taken in November, 1919, in Bond Lake, but only one or two in each of the other localities. It appears to be an uncommon though widely distributed species (Figs. 18-19).

Pleuroxus striatus Schoedler

Point Pelee. Not uncommon during the summer of 1920 in certain ponds.

Pleuroxus procurvatus Birge

Toronto (Grenadier Pond and also smaller ponds and pools), Bond Lake, Wilcox Lake, Point Pelee. The only plankton in which this species was abundant was swept on June 1, 1919, from very shallow water along the margin of Wilcox Lake.

Chydorus globosus Baird

Georgian Bay, Toronto (Lagoon on Island), Point Pelee (Lake Pond). Only a single specimen was found in each of these localities (Figs. 20-21).

Chydorus sphaericus (Müller)

Georgian Bay, Port Sydney, Toronto, Bond Lake, Wilcox Lake, Point Pelee. Most numerous in small weedy pools near Toronto. Variety *punctatus* was the only form of this species present in some plankton taken April 17, 1920, in Bond Lake.

Chydorus faviformis Birge

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Most abundant at Point Pelee, but only a few specimens were found in any of these localities (Fig. 22).

Chydorus barroisi ? (Richard)

Toronto. Although this is supposed to be a southern species, a *Chydorus* which must be either this or an undescribed species closely related was taken on October 19, 1919, in a small weedy pool near Bloor Street and Clendenan Avenue, Toronto. It showed the sharp teeth on the keel of the labrum distinctly but apparently lacked the spine on the postero-ventral margin of the shell. It appeared in company with a great many typical *Chydorus sphaericus* and a careful search not only through this sample of plankton but through collections made from the same pool many times since has failed to disclose another individual (Fig. 27).

Anchistropus minor Birge

Georgian Bay. Four specimens of this peculiar Cladoceran were found in some plankton taken in August, 1905, in weedy shallow water (Figs. 23-24).

Monospilus dispar Sars

Georgian Bay, Point Pelee (Lake Pond). Occurred only in plankton swept from among weeds and not very abundantly (Figs. 25-26).

Alonella excisa (Fischer)

Port Sydney, Bond Lake, Point Pelee. Not very common.

Alonella nana (Baird)

Port Sydney, Bond Lake, Point Pelee. This beautiful striated species was even less common than the preceding one.

POLYPHEMIDAE

Polyphemus pediculus (L.)

Georgian Bay, Port Sydney (Muskoka River), Point Pelee. Fairly common. The specimens taken in June, 1919, from the north branch of the Muskoka River had a peculiar coloration. The tips of the last two pairs of legs as well as the ventral side of the caudal process were of a deep brilliant blue which contrasted strongly with the extreme transparency of the rest of the body.

LEPTODORIDAE

Leptodora kindtii Focke

Georgian Bay, Lake Erie. Common enough in Lake Erie to constitute a most important item of food of ciscoes. Forty-three jumbo ciscoes (*L. eriensis*) taken from July 6 to August 2, 1920, had eaten *Leptodora* very largely along with a few *Daphnia* and *Sida*. In Georgian Bay *Leptodora* occurred in plankton from the deep open water. Some specimens taken September 12, 1905, contained the immature stages of some Trematode. In each case the parasites were quite conspicuous as they were in the very transparent part of the creature's body lying alongside of the digestive tract where they contrasted strongly with their surroundings. It may well be that they were the early stages of a cisco parasite.

The table that follows summarizes the distribution of the Cladocera as given in the preceding pages.

It is evident from this table that the Cladoceran fauna as herein recorded is far from exhaustive for any of the localities studied but taken as a whole it may be considered representative of the south-western portion of Ontario. It is seen to be identical or nearly so with that of the northern portion of the United States as might be expected from the similarity of conditions in the two regions.

During the course of these studies many puzzling forms were encountered especially in the family *Chydoridae*. For example, forms related to *Chydorus*, *Alona*, *Alonella* and *Pleuroxus* combining characters found in the anatomy of two or more of these genera were occasionally seen and the writer feels convinced that many surprises await the future student of these *Cladocera*.

	Georgian Bay	Port Sydney	Toronto	L. Ontario	Bond L. Wilcox L.	L. Erie	Point Pelee
Sida crystallina	+					+	+
Latonopsis occidentalis							+
Latona setifera	+						+
Diaphanosoma brachyurum	+					+	+
" *leuchtenbergianum*	+						+
Holopedium gibberum	+					+	
Daphnia pulex		+	+	+	+	+	+
" *retrocurva*	+			+		+	
" *longispina*	+		+	+	+	+	
Simocephalus vetulus			+		+		+
Scapholeberis mucronata		+	+		+		
Scapholeberis aurita							+
Ceriodaphnia reticulata			+		+		+
" *lacustris*	+		+				
" *quadrangula*	+						+
" *pulchella*							+
Moina affinis							+
Bosmina longirostris	+		+		+	+	+
" *longispina*		+					
Macrothrix rosea							+
Illiocryptus spinifer			+				
" *sordidus*							+
Acantholeberis curvirostris	+	+					
Drepanothrix dentata	+						
Streblocerus serricaudatus					+		
Ophryoxus gracilis	+						
Eurycercus lamellatus	+		+		+	+	+
Camptocercus rectirostris	+				+		+
Kurzia latissima	+		+				+
Acroperus harpae					+		+
" *angustatus*					+		
Leydigea quadrangularis	+		+				+
Alona guttata			+		+		+
" *affinis*	+				+		+
Graptoleberis testudinaria	+		+		+		+
Pleuroxus denticulatus		+	+		+		+
" *trigonellus*		+	+		+		+
" *striatus*							+
" *procurvatus*			+		+		+
Chydorus globosus	+		+				+
" *sphaericus*	+	+	+		+		+
" *faviformis*	+				+		+
" *latus**							
" *barroisi?*			+				
Anchistropus minor	+						
Monospilus dispar	+						+
Alonella excisa		+			+		+
" *nana*		+			+		+
Polyphemus pediculus	+	+					+
Leptodora kindtii	+					+	

*Recorded by Birge "near Lake Erie."

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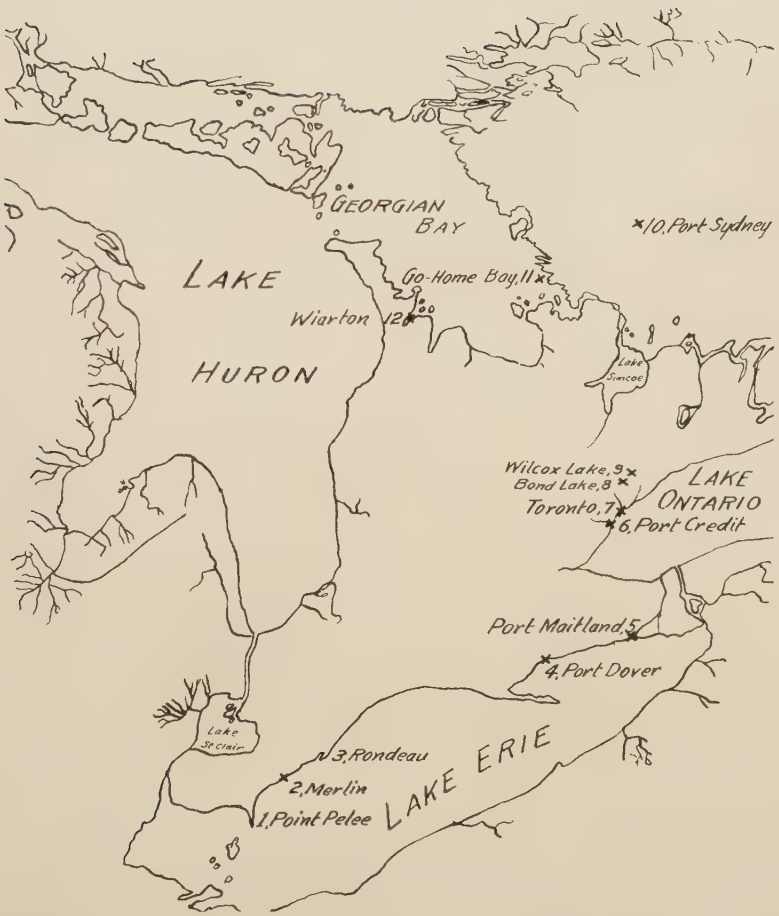

Fig. 1. Map of southwestern Ontario, showing localities from which *Cladocera* were obtained.

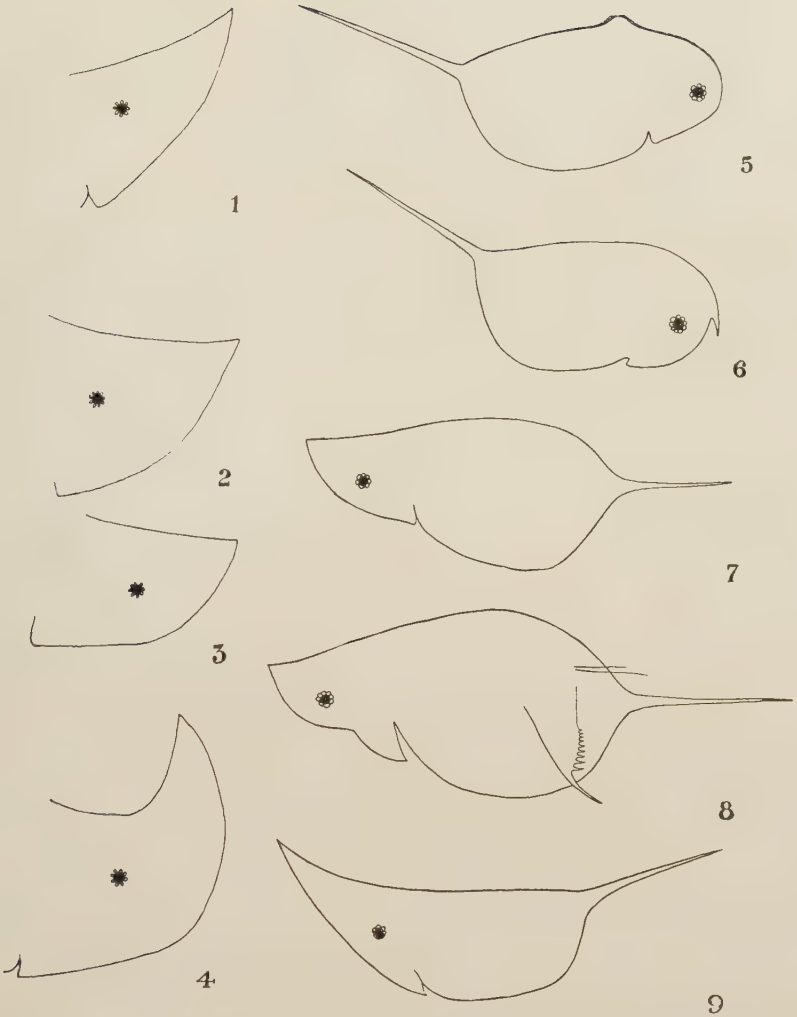

PLATE I. CLADOCERA, ONTARIO

Figs. 1-4. *Daphnia retrocurva*, Rondeau, Lake Erie, June, 1919; variations in cephalic crest.

Figs. 5-6. *D. longispina* var. *hyalina* form *typica*, Grenadier Pond, Toronto; peculiar variations.

Figs. 7-9. *D. longispina* var. *hyalina* form *galeata*, Georgian Bay; some extreme variations.

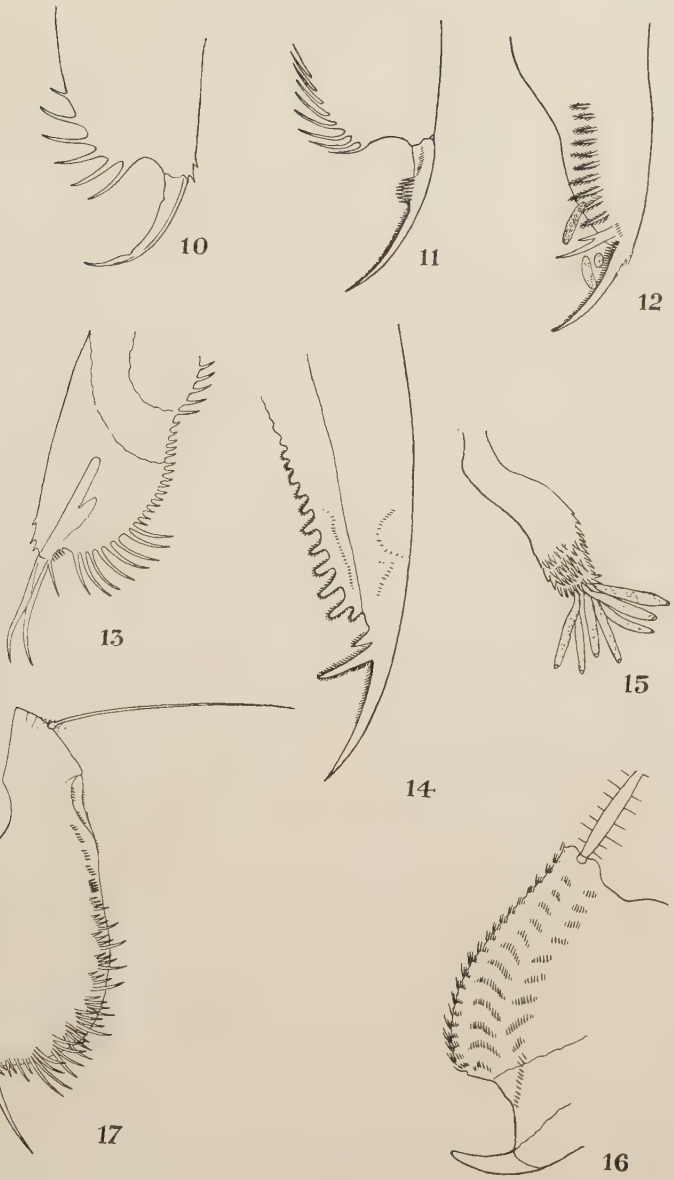

PLATE II. CLADOCERA, ONTARIO

Fig. 10. *Scapholeberis aurita*, end of post-abdomen; Fig. 11, *Ceriodaphnia reticulata*, end of post-abdomen; Fig. 12, *Moina affinis*, end of post-abdomen; Fig. 13, *Illiocryptus sordidus*, post-abdomen; Fig. 14, *Ophryoxus gracilis*, post-abdomen; Fig. 15, *Drepanothrix dentata*, antennule female; Fig. 16, *Drepanothrix dentata*, post-abdomen; Fig. 17, *Leydigea quadrangularis*, post-abdomen.

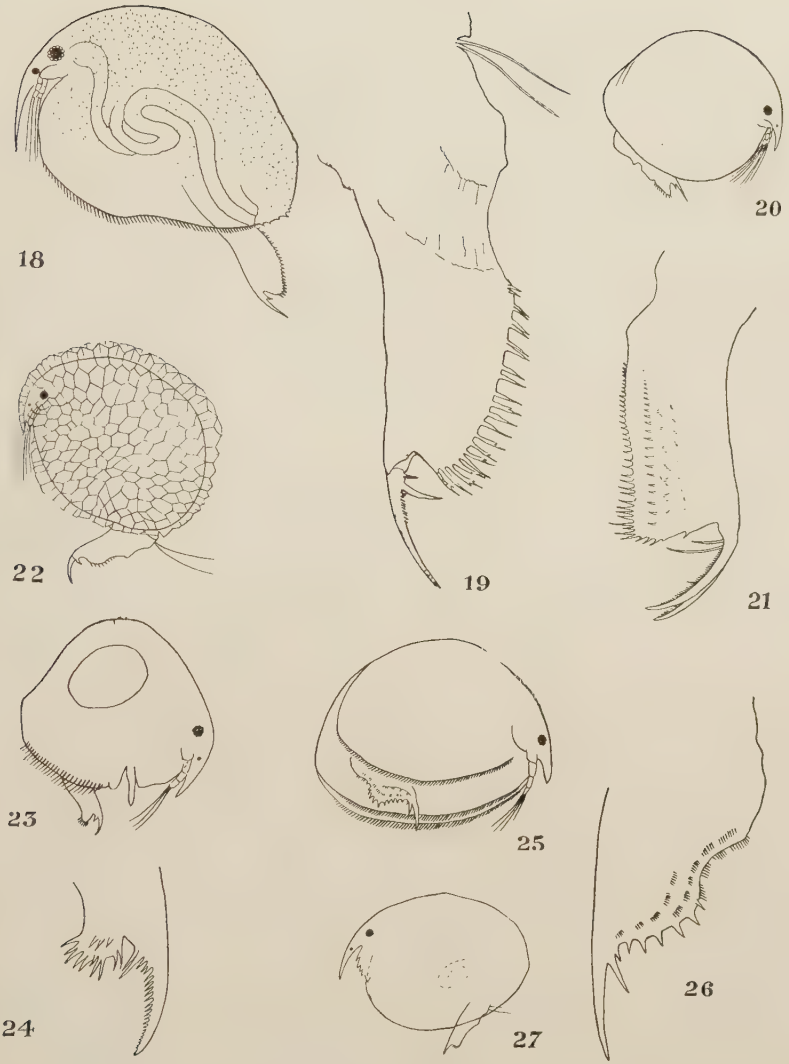

PLATE III. CLADOCERA, ONTARIO

Fig. 18, *Pleuroxus trigonellus*; Fig. 19, *Pleuroxus trigonellus*, post-abdomen; Fig. 20, *Chydorus globosus*; Fig. 21, *Chydorus globosus*, post-abdomen; Fig. 22, *Chydorus faviformis*; Fig. 23, *Anchistropus minor*; Fig. 24, *Anchistropus minor*, end of post-abdomen; Fig. 25, *Monospilus dispar*; Fig. 26, *Monospilus dispar*, end of post-abdomen; Fig. 27, *Chydorus barroisi*?

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 9

BREEDING HABITS OF THE LAND-LOCKED SEA LAMPREY
(*PETROMYZON MARINUS* VAR. *DORSATUS* WILDER)

BY

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BREEDING HABITS OF THE LAND-LOCKED SEA LAMPREY

(*PETROMYZON MARINUS* VAR. *DORSATUS* WILDER)

Nearly all that has been recorded concerning the life-history of the land-locked sea lamprey (*Petromyzon marinus dorsatus* Wilder) refers to the earlier description of Jordan and Fordice (1885) and the very inclusive study by Gage (1893) and his associates of the variety as it occurs in Cayuga and similar lakes of northern New York. For many years it has been known locally that a lamprey occurs in Lake Ontario at least some miles east and west of Toronto, where it is sometimes greatly in evidence, attaching itself temporarily to boats in motion or more especially to food-fishes and thus brought up by fishermen operating gill nets for whitefish and lake trout in the open waters. This lamprey has been confused to some extent with the silver lamprey (*Ichthyomyzon bdellium* Jordan). Its identity with *P. marinus dorsatus s. unicolor* was suggested by Bensley (1915), as a result of studies of the animal and of the surface wounds on fishes in relation to reports of fishermen as to occasional lamprey marks on whitefish in Georgian Bay; and confirmed by Huntsman (1917) as a result of a systematic review of the known records of lampreys from Ontario waters. So far as the writer is aware no young have been recorded hitherto from the Toronto area, though there is a single metamorphosed specimen of 13.5 cm. taken in a swamp near Whitby in the university collection.

While it is evident from what is known of the glacial history of the Great Lakes Basin that a community of conditions is to be expected as between the New York lakes and Lake Ontario, and also between both and the Gulf of St. Lawrence, the relative isolation of the habitat previously described lends interest to its more open occurrences in

Lake Ontario and also to the comparison of its breeding habits and development with that of the Cayuga lamprey. At the same time it will be recognized that the term "land-locked" as applied to the animal is largely a matter of descriptive convenience. The case is analogous in some respects to that of the land-locked sea salmon in its original occurrence in Lake Ontario. Of these and other species of fishes related as respectively fresh water and marine we know neither the nature of the original medium nor the environmental factors associated with their varietal and specific differences.

On Friday, May 27, 1921, Mr. J. R. Dymond of the Department of Biology reported that large numbers of land-locked sea lampreys were in the Humber river, just west of the city of Toronto. The vast majority of those he saw, and they numbered hundreds, were in a small rocky pool immediately below the Lambton weir; many were swimming about, others hung on to the rocks from which they could be picked by hand. They appeared to be blocked in their ascent of the stream by the weir, which is about three feet high. Mr. Dymond did not see any nests on this date. It was then decided to attempt to follow the progress of the breeding season, and with this object in view frequent visits were made to the river during June.

The stretch of the river in which nests were found is about three-quarters of a mile long and terminated upstream by the weir already mentioned; no nests or adults were seen above this in spite of careful search. Downstream, nests were not discovered below the rapids at the Old Mill Bridge, below which point the river becomes deep with a muddy bottom for the rest of its course to Lake Ontario, a distance of about two miles. Between the weir and the bridge the river averages about thirty yards in width and two feet in depth at this season of the year, with occasional holes as much as six feet deep. The river bed is composed of clean gravel or shingle interrupted here and there by large flat slabs of solid rock, and the stream is broken up by frequent rapids, none steep enough to make real 'white water', although the larger are difficult enough to wade against. The general

direction of the stream is from north to south and the valley is so wide that in spite of the high banks (80-100 feet) the sun reached the water by 8 o'clock in the morning (standard time).

As was subsequently found during repeated wanderings along this stretch of the river, nests were excavated only in the more rapid regions and indeed only in the shallower parts of these. The majority were in not more than a foot of water and none were seen at a greater depth than two feet. Large stretches of gravel of apparently exactly the same physical qualities as in the rapids, but covered instead by comparatively slowly moving water, were completely neglected, while a few yards up or down stream nests were abundant.

The nests are shallow depressions in the bed of the stream usually oval in outline, with the long axis in the direction of flow. They vary considerably in size, from about 12 inches by 18 inches to 24 inches by 30 inches. They are constructed usually by a pair of lampreys, but single animals have been seen working, and in one case at least two pairs occupied one large nest, all four individuals moving stones.

The stones moved are in general not larger than an inch in diameter, and most of them are smaller than this; occasionally, and with great effort, stones as big as two inches across are dragged from the excavation. In no case were two animals seen combining to move one stone, although in a number of cases this would have enabled them to make a much more convenient nest; if a stone too large to be moved by individual effort lies within the ambit of the nest, it remains. The material is deposited on the downstream side of the nest so as to form a kind of parapet of which the curve conforms to that of the oval hollow. An animal, having attached itself to a stone, allows itself to drift tail first with the current, until its mouth is over the downstream edge of the nest, it then brings itself to a halt with a sharp movement of its tail and at once drops the stone in position. While choosing stones the animal's movements are rather indeterminate; it will often lift and drop immediately a number of

pebbles before carrying one clear, and often it will remain stationary in the nest for minutes on end, either adhering to a large stone or lying at rest in the still pocket of water caused by the parapet. At the upstream edge of the nest there is nearly always a stone of markedly large size. No factor determining the site of the nest could be discovered other than the general ones of gravel of the right degree of coarseness and a sufficiently rapid current; given these, nests seemed to be impartially distributed in mid-stream or near the banks, at the upper edge of a rapid or down its full extent; in places they were so numerous as to suggest aeroplane photographs of heavily shelled fields.

The actual process of laying was watched a number of times. The two animals concerned cease carrying stones and take up a position with their heads at the upper edge of the nest; this is achieved in one of two ways; either both attach themselves to the large stone already mentioned, or the female alone takes this position, the male clinging to the top of her head; at once after this the posterior halves of their bodies twist together for about a complete turn and simultaneously make very rapid flapping movements, so fast, indeed, as to be almost vibrations. During this process, which lasts only a few seconds, eggs may be seen pouring from the female as a number of small white specks, which become mixed with the very small stones and sand stirred up by the agitation of the parents' bodies. As soon as this movement ceases eggs and sand together settle down at the bottom of the nest. The male and female then separate and resume their stone-hauling, often moving stones from points a foot outside the nests and placing them on the parapet, but after a few minutes the laying process is repeated; how often this interruption and resumption of laying may occur was not determined, but certainly as many as four.

In the large nest already mentioned as being the work of four animals one and the same male was seen to pair with each of two females, eggs from different mothers being mixed in the nest.

The eggs when they are first laid stick so firmly to stones

that any attempt to detach them usually destroys them; after about fifteen minutes, however, they do not adhere at all so closely and may be washed off with a gentle stream of water from a pipette; in the course of a day or two they lie loose among the pebbles.

During the period over which nesting was watched the temperature of the water varied from 18° C. on June 4th, to 23° C. on June 21st and 27th, the temperature being taken between 8 and 9 o'clock a.m., standard time.

The nesting season lasted approximately a month. As already noted abundant adults were seen on May 27th, but no nests. On June 1st nests were found in a rapid stretch about six hundred yards below the weir; the animals had apparently relinquished the attempt to go higher up-stream, since on this date none were seen in the pool, nor were any seen subsequently this far up. The nest of June 1st had probably been provided with eggs the previous day, as those from which samples were taken all showed segmentation stages. The last nestings observed were on June 21st and no adults were seen later than June 22nd.

As to whether the parents die after spawning I cannot make a definite statement. I have, however, a strong feeling that they do not, and this opinion is based on the very small number of dead lampreys as compared with the abundance of the living seen during the nesting season. During June not more than a dozen or a dozen and a half dead were seen either in the nesting reach itself or in the slower stretch of water between this and Lake Ontario, while in the course of a few hours 150 living individuals were taken from the pool below the weir at the beginning of the season. If, then, the parents die at the end of the breeding season, they appear to return first to the lake, for it is hardly imaginable that so many individuals dying in so short a space of time and in so limited an extent of water should leave so slight a trace of the event.

An attempt was made to determine the time that elapses before the young leave the nest, and although the data are not quite conclusive, a probable estimate can be made.

There are two sources of possible error, first the necessity of disturbing the pebbles at the bottom of the nest among which the larvae are developing. The young after hatching are found one to two inches below the surface and in the undisturbed nest have presumably reached a position in which they are not affected by the flow of the stream; to get samples the overlying stones have to be turned gently aside with the point of a pipette until the larvae appear, when they are at once sucked up. In this process a number are inevitably dislodged from their crannies among the pebbles and swept away by the current, and it is not improbable that during the readjustment which must follow any such violent invasion of the colony new circulations of water are established, carrying still more of the young prematurely from the nest, which will thus be empty before its normal time. This error involves probably not more than two or three days.

The other complication is the difficulty of deciding when a nest is quite empty. The larvae are often distributed in patches over different parts of the nest, and while the greater part of the nest may not reveal a single larva, finally a thickly populated area may be touched by the pipette. The danger lies in overlooking such spots, and this is the greater since thoroughly to search a nest is a tiring procedure, the most practicable way being to kneel by it and, using a water-glass for clearer observation, bend close over it while turning the stones. With practice, however, likely spots are soon recognized, and in this case again the total inaccuracy is probably not large, almost certainly within the limits of variation due to changes in temperature. The two errors, further, tend to balance one another.

A nest called No. 3 may be taken as typical. It was first observed on June 1st, and the eggs were within a few hours of laying; on June 22nd no more larvae could be found in it. It should be mentioned here that specimens collected from this nest at various times and allowed to develop in the laboratory had by this time become quite transparent owing to the gradual disappearance of the shining white

yolk, that they were taking solid food from the mud provided, that they could swim powerfully and fast, and that they always made vigorous efforts to get under small stones or into the mud in the vessel. They were thus properly equipped to start the new phase of their existence. It is certain that these laboratory-bred animals were normal since they were compared time and again with specimens brought freshly from the nest, and no difference could be found; they could be used, therefore, as a sort of indirect check on the likelihood of the nest's being fully vacated.

The young, therefore, left the nest after about three weeks: this result is confirmed by observations on other nests and may be accepted as the average length of time for such conditions as prevailed during the breeding season of 1921. That the young leave the nest voluntarily and by their own exertions can, I think, hardly be doubted, since during the breeding season no rain fell after June 4th, and the stream became steadily lower and consequently the current less likely to disturb the nests. The young hatch out of the egg in seven or eight days.

I have not yet been able to discover where the next stage of life is spent despite careful examination of many samples of mud collected below the spawning reach at all depths down to 4 feet.

It is worth remark that in all the nests examined a number of eggs failed to develop; the percentage was not accurately determined, but is estimated at 10 to 20 per cent. of the total. These eggs become a light brown colour and may be found in the nest throughout the whole period of 'incubation.' On examination they prove to be covered with a delicate felt-work of almost colourless fungal hyphae, and if any of these infected eggs are by accident introduced into a dish in which larvae are developing there is formed on the floor of the vessel a strong growth of fungus, in which the larvae, as they become active and attempt to burrow, entangle themselves and perish. The causes of this non-development were not discovered, but three possibilities seem available; (1) that some eggs are incapable of fertilization, (2) that the

rather haphazard method of fertilization fails to ensure that a sperm reaches every egg, (3) that the eggs begin to develop, but owing to some weakness are at an early stage invaded by the fungal parasite. Further research is required to clear up this point.

Finally it seems worth while to call attention to the combination of unattached eggs with the position of the nest in the fastest accessible water, a condition that would hardly be, *a priori*, expected. It is true that for the first few minutes of their free existence the eggs are attached, apparently just long enough for the stones to which they adhere to settle into a permanent arrangement under the current conditions obtaining in the nest; subsequently they lie scattered loosely among the pebbles. The parapet on the downstream side of the nest certainly creates an eddy of comparatively still water in the nest, but a very slight disarrangement destroys the effect of this, as many experiences while collecting have shown. The aetiology of so curious a laying habit presents some interesting problems.

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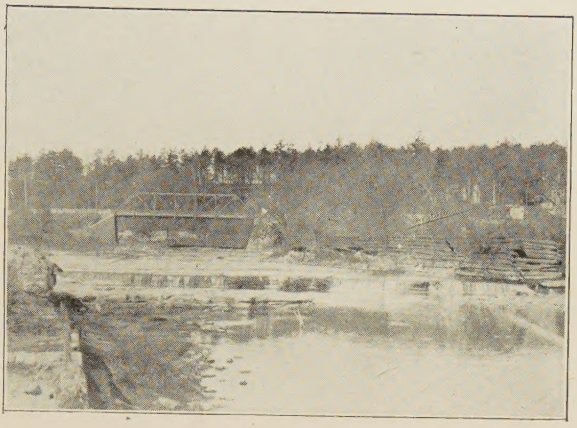

Fig. 1. The weir at Lambton.

Fig. 2. A typical rapid, the site of a number of nests.

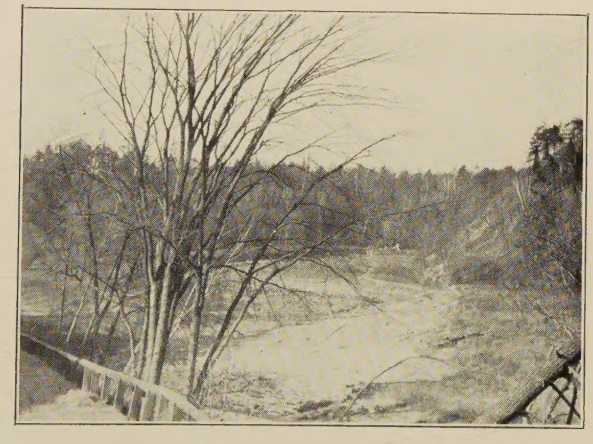

Fig. 3. A characteristic reach of the R. Humber, showing a succession of rapids and the nature of the banks.

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